

PHONOLOGY OF ARTICULATION

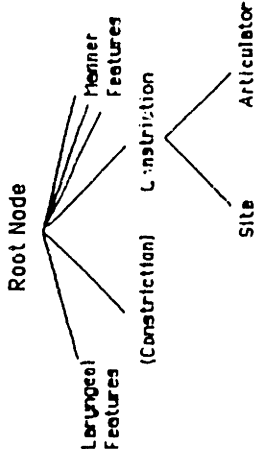
by

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Submitted to the Department of Linguistics and Philosophy
on October 22, 1989 in partial fulfillment of the
requirements for the degree of Doctor of Philosophy in
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ABSTRACT:

In this thesis, I focus on the phonological representation of the articulatory component of speech production. I argue for a phonological constituent called the Constriction Node, which represents the constriction gesture. Within the segmental tree (cf. Clements (1985), Sagay (1986)), the Constriction Node is a daughter of the Root Node (in the sense of the Clementis/Sagey model). It itself dominates the Site, which corresponds to the constriction location, and the Articulator, which corresponds to the organ executing the constriction gesture. The model of segment representation which includes the Constriction Node is represented as follows:



In this model, the Site ranges over the features Labial, Anterior, Palatal, Velar, and Pharyngeal. The Articulator can have either of the values: Lower Lip, Tongue Blade, Tongue Body, Tongue Root.

The constriction model reconciles two traditions of segment characterization: the IPA tradition, which stresses the importance

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Submitted to the Department of
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of the constriction, location features, and the SPE (Chomsky and Halle (1968)) tradition of giving priority to the features based on the active articulator. It adopts the hierarchical view of segment representation introduced by Clements (1985) and Sagey (1986). In particular, it adopts the concept of an Articulator as it is developed in Sagey (1986).

The constriction model offers a view of segment representation closely modeled on the physical reality which it represents: the constriction structure is a necessary element of speech production.

On the phonological side, the main advantage of the constriction model is that it makes all articulation features equally available to consonants and vowels; this is what allows it to account for vowel/consonant interaction phenomena (e.g., mutual vowel/consonant palatalization, velarization, and pharyngealization, among others). Also, by offering more structured representations, this model goes even further than the previous models in the direction of limiting the number of phonological processes which do not occur.

This thesis is organized as follows: chapter 1 introduces the constriction model. Chapters 2 and 3 argue for the phonological constituent Articulator, and the phonological constituent Site (respectively) on the basis of the examples which can be analyzed only in terms of these features. Chapter 4 deals with the structure within the Constriction Node. In chapter 5, the articulatory basis of Site and Articulator features, and the phonological motivation for treating vowels in terms of such features are discussed. Chapter 6 discusses some residual questions in the representation of consonants. Finally, chapter 7 considers the consequences that follow from applying the constriction model in the analysis of various phonological processes.

Thesis Supervisor: Donca Steriade
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1. Introduction

In order to communicate by means of speech, humans must be able to alter the shape of their vocal tract so as to produce sounds which the human auditory system is able to distinguish. There are a number of things we can do to create the contrasts we can hear -- we can vibrate (or not) our vocal cords, lower (or raise) the basic frequency of vibrations, lower (or raise) our velum, blow the air out (or draw it in), but most likely, these gestures alone would not suffice to develop a good phonemic inventory. In fact, no known human language relies solely on these gestures.

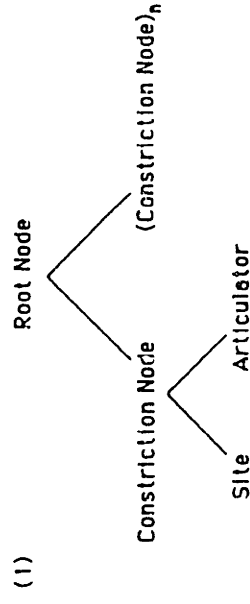
Without doubt, the richest source of audible contrasts are the gestures executed with the tongue and the lips, which form the articulatory component of speech production. The exact role of these gestures has had various interpretations in the field of phonetics. In one school of thought (e.g., Ladefoged (1962), (1975), Catford (1977), Malmberg (1963), etc.), the activity of the tongue and lips is interpreted differently for consonants and for vowels. In the production of consonants, the role of the tongue and lips is to obstruct the air flow -- completely for stops, and partially for continuants. In the production of vowels, neither the lips nor the tongue are thought of as obstructing the airflow; rather, they assume various shapes and ultimately modify the shape of the vocal tract.

This view of speech production is reflected in the characterization of speech sounds by the International Phonetic Association. The IPA system characterizes consonants in terms of the point of maximum constriction, and vowels in terms of the position of the highest point of the tongue.

More recently, a different view of speech production, based on the notion that all speech sounds involve a constriction gesture, has dominated phonetic research. It is proper to trace the origins of this view to the research done in acoustic phonetics on the relationship

between the acoustic properties of speech sounds and the vocal tract configurations and particularly to the work by Stevens and House (1955), who have extended the concept of constriction to the treatment of vowels. Their work has influenced the tone of discussion for both acoustic and articulatory phonetics (cf., Stevens (1972), (1988), Fant (1960, 1973), Jakobson and Waugh (1979), Wood (1975), (1979), (1982), Perkell (1979), Perkell and Cohen (1987), (1989), Perkell and Nelson (1982), (1985), Mbayati, Carre, and Guerin (1988), Carre and Mbayati (1989), etc.), but has had very little effect on the phonological treatment of speech sounds.

The model of feature representation proposed in this thesis is designed around the concept of constriction. Constriction is represented as a function of two variables: the Site (= point of articulation) and the Articulator, where the Site may range through Labial, Anterior (cover for the dental and alveolar sounds), Palatal, Velar and Pharyngeal* specifications. The Articulator may take on the following values: Lower Lip, Tongue Blade, Tongue Body, Tongue Root and Glottis. Let us represent this model as follows (the tree below contains only the articulatory features (without the stricture features, though); it ignores all other speech production processes (phonation, nasality, and airstream mechanism)):



The model in (1) formally expresses the idea that out of all possible gestures that can be executed with the tongue and lips, only those

* Following McCarthy (1989).

that result in a constriction can create vocal tract configurations suitable for the production of speech sounds.

The model in (1) claims also that all articulatory configurations that can result in a constriction gesture (in other words, all configurations that are physically possible) will result in a possible speech sound. A comparison between the articulatory spectrum of an average human and the inventory of the attested speech sounds (e.g., Maddieson (1984)) reveals that this generalization is largely correct. Consider all logical Site/Articulator combinations, with the physically impossible ones marked with an asterisk: Labial/Lower Lip, Labial/Tongue Blade, Labial/Tongue Body, *Labial/Tongue Root, Anterior/Lower Lip, Anterior/Tongue Blade, Anterior/Tongue Root, Palatal/Tongue Body, *Anterior/Tongue Root, *Palatal/Lower Lip, Palatal/Tongue Body, *Palatal/Tongue Root, *Velar/Lower Lip, *Velar/Tongue Blade, Velar/Tongue Body, *Velar/Tongue Root, *Pharyngeal/Lower Lip, *Pharyngeal/Tongue Blade, Pharyngeal/Tongue Body, Pharyngeal/Tongue Root. After weeding out the starred ones, we are left with ten combinations which represent physically possible gestures. The only ones in this group that may raise doubts as the candidates for possible speech sounds are: Labial/Tongue Blade, Labial/Tongue Body, and Anterior/Tongue Body. The remaining combinations pattern onto attested speech sounds as follows:

(2) Labial/Lower Lip:	p, b, m, u, o
Anterior/Lower Lip:	f, v, ɱ
Anterior/Tongue Blade:	t, d, s, z, θ, ð,
Palatal/Tongue Blade:	ç, dʒ, ʃ, ʒ
Palatal/Tongue Body:	c, ɟ, ɕ, ʝ, ɐ
Velar/Tongue Body:	k, g, x, ɣ, q, ɣ̥, ɣ̥̥, u, o
Pharyngeal/Tongue Body:	ʕ, ʕ̥, ʕ̥̥
Pharyngeal/Tongue Root:	h, ʕ̥̥̥

As for the three questionable ones -- the Labial/Tongue Blade combination is utilized by some languages, as demonstrated by Maddieson (1987). Also, there are arguments for positing the

existence of vowels which involve an Anterior/Tongue Body constriction (see 5.3.2 for the discussion). Only the Labial/Tongue Body combination does not appear to be utilized by any language, despite the fact that it is possible for a human to utter a Labial/Tongue Body sound. Note however, that such a sound would involve the tongue blade either protruding from the mouth, or curled up underneath the tongue body. Both of these gestures are articulatorily awkward, and do not occur in any speech sound. It is conceivable that the conditions on possible speech sounds prohibit such gestures.

The approach I am taking here is not unreasonable: there are numerous restrictions on possible speech sounds which have to do with the physical limitations, and which must be treated as such under any model of phonological representation. A speaker of a language does not need to be instructed not to utter a pharyngeal nasal, an oral labio-dental stop, or a nasal fricative, given that such sounds cannot be produced. In other words, the model of linguistic competence should not be concerned with physical impossibilities. Most likely, impossible feature combinations such as Tongue Root/Anterior are ruled out by the same mechanism which prevents a normal human being from voluntarily bending the knee the wrong way.

The model in (1) conceptualizes the articulatory component of speech. In that respect, there is nothing new about it, as most feature classifications stress the importance of the articulation. Its main novelty lies in the fact that it departs from the tradition of expressing the articulatory features either primarily in terms of the constriction location (as in the IPA system of treating consonants), or primarily in terms of the features describing the behavior of the articulators involved in speech production (as in Chomsky and Halle (1968), and the proposals that have recently evolved from theirs, cf., Halle (1983), Clements (1985), Sagey (1986)). Instead, I argue that both aspects of speech sound production are phonologically relevant,

and I propose to incorporate both in the model of feature representation.

There is yet another difference between this proposal and the previous ones: it introduces the idea that the mental representation of a speech sound includes a constriction node which mediates the relationship between the Site and the Articulator features. Since this model has no means of representing sounds in terms of an articulator or a site which do not participate in a constriction, it makes a very strong claim about the nature of phonological representation of speech sounds, namely, it predicts that only the features of the site and the articulator involved in a constriction may be phonologically relevant.

The main (and perhaps, the ultimate) strength of a feature representation lies in its explanatory power as applied to phonological processes, conditions on representations, observed phonemic contrasts, etc. The present thesis is almost entirely devoted to the goal of defending the constriction model on these grounds. However, in order to justify attributing certain properties to this model or its various nodes, I shall appeal at times to various physical aspects of speech production. To make these moves licit, I shall begin by establishing the links between the components of the constriction model and the phonetic reality which it (indirectly) represents.

1.1 The Phonetic Reality of the Constriction Model

It is an interesting question (also one that I will not pursue too deeply), how closely phonological representation should resemble phonetic representation. While there are obvious advantages to treating phonological segments in terms of labiality, coronality, or anteriority, that is, in terms of the configuration of the vocal tract necessary for the production of the sounds which the phonological segments represent, it is fairly obvious that certain aspects of phonetic representation do not have phonological counterparts. Some well known examples of this include these:

speech is a continuum that does not lend itself to any simple segmentation, but phonological segments are discrete units; speech sounds occur in time, and are by no means the same at all stages, but phonological segments are icons which represent various target positions for various articulatory structures, not necessarily simultaneously achieved (in other words, for some sounds there is no "time slice" which would correspond to the phonological representations associated with these sounds). These facts show that bringing phonology closer to phonetics is not an a priori desirable objective.

We are not yet sufficiently knowledgeable about the processes which relate phonological to phonetic representations, to decide a priori where the boundaries of phonology-phonetics correspondence lie. The position that I take in this thesis with regard to this problem is pragmatic: to the extent that certain properties of phonetic representation can be useful in accounting for aspects of phonology, they should be incorporated into phonological representation.

I appeal to the phonetic reality of the constriction gesture in order to be able to attribute to the Constriction Node the properties with which the constriction gesture is associated, namely, having one location and one articulator which executes it. Of course, if the Constriction Node has a "physical reality", so must the nodes under it. This means that the site and the articulator features should map uniquely onto real articulatory properties of sounds.

It is rather easy to demonstrate that about the articulator features: X-rays and other phonetic records show that the primary articulator and its shape are largely invariant for all tokens of (what we perceive as) one sound. Also, we can call on the considerable success of phonological theories which have based phonological features on the behavior of the articulators, for the support for this aspect of the constriction model.

As for the site features, we are in a somewhat different situation. While the importance of the constriction location in the production of consonants is well recognized (cf. the IPA treatment of consonants), there has been a considerable tradition of characterizing vowels without any reference to constriction. Instead, the model of vowel articulation that has dominated research in phonology, and to some extent, in phonetics, over the last century, is the tongue arch model introduced by Alexander Bell in 1867. In essence, this model expresses the articulatory properties of vowels in terms of the position of the highest point of the tongue arch in the front-back and high-low space.

The tongue arch model has been widely accepted in phonology, as it seems to be fairly well suited for expressing the phonological processes affecting the vowels (such as the backness and height harmonies). In phonetics, on the other hand, the success of this model has been dimmed by X-ray findings (Meyer (1910), Russell (1928), etc.), which have revealed a discrepancy between the predictions that this model makes with respect to the height of the vowels, and the height of the tongue arch actually observed. The X-ray tracings of vowels from languages that display the tense-lax opposition show persistently higher tongue position for the tense vowels characterized as mid by the model, than for the lax vowels which are labeled high.

Dissatisfaction with the tongue arch model has led to a number of proposals (Jakobson, Fant, and Halle (1952), Jakobson and Waugh (1979), Ladefoged, Declerck, Lindau, and Papçun (1972), etc.) which viewed vowel production in terms of reaching acoustic targets, by possibly variable articulatory means.

Renewed interest in the articulatory aspects of vowel production has sprung up in the context of research which studies the relationship between the acoustic effects of speech sounds and the vocal tract configurations (Stevens and House (1955)). Stevens and House view the production of vowels as involving a constriction in the vocal tract, and they express the articulatory properties of

vowels in terms of the location and the degree of the constriction, and the degree of lip opening. These parameters, when translated into numbers (constriction location -- in terms of its distance from the glottis, degree of constriction -- in terms of the radius of the opening between the articulator and the upper surface of the vocal tract at the constriction), suffice to determine the dimensions of the rest of the vocal tract. Given these, the acoustic properties of speech sounds can be computed.

The "quantitative" model of vowel articulation developed by Stevens and House (1955) has influenced acoustic research in vowel production, e.g., Fant (1960), Fant (1973), Lindblom and Sundberg (1971), Stevens (1972), (1988), Mrayati, Carre, and Guerin (1988), Carre and Mrayati (1989), etc. It has also inspired the articulatory studies of vowels (e.g., Wood (1975), (1979), (1982), Perkell (1979), Perkell and Cohen (1987), (1999), Perkell and Nelson (1982), (1985), etc.). Most importantly, at least from the point of view taken in this thesis, this model has opened a possibility that the constriction location might represent an invariant aspect of vowel articulation, and therefore may satisfy the requirements of a phonological feature.

This view was taken up in the work of Sidney Wood (mentioned above). Wood (1979) rejects the tongue arch model of Alexander Bell (1867), arguing that the disparity between the predicted and actually observed tongue heights disqualifies this model as a tool for describing the articulatory properties of vowels. Instead, he advocates the return to the tradition of characterizing vowels in terms of the place of maximum constriction. (The articulatory model based on the constriction location has been known and handed down to us by the Sanskrit grammarians, cf. Varma (1929), Allen (1953)).

On the basis of X-ray tracings of 38 vowel sets, Wood argues for a model of vowel production which distinguishes four regions of maximum narrowing in the vocal tract: palatal (for i-like and e-like

vowels), palato-velar (for u-like vowels), upper pharyngeal (for q-like vowels) and lower pharyngeal (for a-like vowels)*.

Wood's additional arguments for expressing articulatory properties of vowels in terms of the place of maximum constriction come from physiological considerations. He analyzes the position and the movement* of the extrinsic tongue muscles: genioglossus, styloglossus, hyoglossus, and palatoglossus, and concludes that each of these muscle groups is ideally situated for executing tongue body constrictions at the four target locations.

In a similar vein, Stevens and Perkell (1977) point out the inadequacy of characterizing features [low] and [high] solely in terms of the high-low position of the midline of the tongue. Instead, they propose to specify these features in terms of "tongue-surface contact with other surfaces" (Stevens and Perkell (1977), p. 330).

Virtually all of Wood's stronger conclusions (e.g., about the phonological adequacy of his model, about the sufficiency of the constriction location and jaw opening parameters for articulatory characterization of vowels, and even about invariability of the constriction location for some vowels, have been challenged: by Halle (1983), on the strength of phonological arguments, Catford (1981), and Jackson (1988) on the phonetic grounds, and by Fischer-Jørgensen (1985), on both grounds.

In the chapter on vowel representation (chapter 5), I shall consider all of these criticisms, and try to develop a view of vowel representation that is both articulatory and phonologically acceptable. The result of Wood's work that will be defended and kept as the basis of phonological representation of vowels proposed in this thesis is that the region of constriction constitutes a property of vowel articulation stable enough to be used for vowel

* Obviously, there are differences between Wood's proposal and mine, as far as the inventory of Sites (primary constrictions locations) is concerned. These differences will be discussed in more detail in 5.3.

* On the basis of electromyographic evidence and anatomical descriptions.

identification. The claim that production features which are based on the behavior of the dorsal articulator are not relevant in the phonological characterization of vowels will be rejected.

1.2 Neuro-physiological Basis of Articulatory Features

A necessary criterion for a phonological feature is that its execution be verifiable by the brain. Neither the articulators (lower lip, tongue blade, tongue dorsum) nor the sites (labial, anterior, palatal, velar, etc.) can communicate with the brain directly via motor control: the articulators are rather passive bodies of flesh which are manipulated by the various muscles of the tongue (or, in case of the lower lip, the muscles of the lip), and the sites constitute a fixed structure. What then allows the brain to operate on features like [anterior] or [coronal]?

It has been suggested in the literature that the implementation of phonological features is aided by a tactile experience: due to high sensitivity of both the articulator surfaces and the walls of the vocal tract (evidenced, for example, by the results of the experiments testing stereognostic* capabilities of humans, cf., Grossman, Hattis, and Ringel (1965)), the brain is able to evaluate both the regions and the extent of contact between the articulators and the vocal tract surfaces.

Studies have been done which reveal a direct relationship between the articulatory skills and stereognostic abilities in humans. For example, in an experiment reported by Ringel, House, Burk, Dolinsky, and Scott (1970), stereognostic abilities of children with no speech disorders and children with mild-to-severe articulatory disorders were compared. The results of the experiment have shown that children with articulatory disorders make more errors than children with no disorders, and that the number of errors increases with the degree of the impairment in a child.

* Oral stereognosis = ability to recognize shapes of objects placed in mouth.

In a paper which explores the concept of 'orosensory' correlates of phonological features, Stevens and Perkell (1977) show that commonly postulated articulatory correlates of a number of features (e.g., [high], [low], [anterior], etc.), which orient the articulators in space, do not represent the actual gestures with which these features are implemented. They propose to replace the traditional articulatory definitions of features with the orosensory correlates which are "distinctive tactile and proprioceptive responses within the vocal tract" (Stevens and Perkell (1977), p. 325). For example, the feature [+anterior] is characterized in this framework as involving a contact between the tongue tip and the edges of the tongue blade with the palate at its periphery, which gives rise to the tactile stimulation in both the tongue and the palate.

Ideally, all phonological features which refer to articulatory structures should be definable in terms of orosensory responses that they trigger. In the phonological representation proposed in this thesis, the Constriction Node and most nodes below it are easily characterized in those terms. This is trivially true of the site and articulator features. As for the features dominated by the articulators (e.g., [distributed], [high], [back], etc.), most of them too yield to orosensory interpretations; for example, the feature [distributed] in its negative value can be characterized by orosensory responses in the tongue tip area (contact in the case of stops, and turbulence in the case of fricatives) and no such responses in the tongue blade area. In its positive value, this feature is associated with an orosensory experience along the tongue blade. The feature [lateral] is characterized by a break in the contact between the sides of the tongue blade and the palate, and the turbulence in those areas.

* Stevens and Perkell define this term as follows: "The term orosensory [...] refers to the sensory systems in the various vocal-tract structures from the larynx to the lips. It includes sensations due to tactile stimulation, pressures, and turbulent airflow, as well as sensory information from muscle spindles, tendon organs and joint receptors" (Stevens and Perkell (1977), p. 325).

There are, however, features which are not easily interpreted in terms of the orosensory response. For example, the feature [back], which traditionally has been characterized in terms of the tongue body position in the front-back space, resists such a treatment, at least in terms of the tactile response.⁵ A possible orosensory correlate of this feature could be the motor activity required for shifting the tongue body forward and backward.

Even more troublesome in that respect are the stricture features. Here, however, the difficulties lie (probably) in the fact that we are far from understanding the phonology of these features. For example, observations of various sonority hierarchy phenomena suggest that there is one stricture feature which is multi-valued, and which ranges over stop - fricative - nasal - liquid - glide - high - mid - low values. However, with the exception of height harmonies among vowels, there are very few phonological phenomena which manipulate these values. Again, the fact that stricture features can be manipulated among vowels, but not among consonants is puzzling.

As for positing an articulatory correlate of a single stricture feature, one that would trigger distinct orosensory responses for all its values, we are probably very much at the guessing stage. As I have already observed, the degree of constriction opening is not the most felicitous choice for characterizing vowels, as it does not differentiate between vowels as distinct as i and a. A possible way of looking at this feature would be in terms of the degree of the airflow obstruction, where the unobstructed airflow would be characterized by the vocal tract configuration for breathing. What gives this approach a certain attractiveness, is that it affords us a

⁵ Stevens and Perkell (1977) suggest that [-back] involves the contact of the edges of the tongue tip with the lower incisors, whereas [+back] requires that there be no such contact. I do not consider this approach, for two reasons: first, it appears perfectly natural for me to make contact between the tongue tip and the lower incisors for any vowel. Even if this contact is not required in the case of back vowels, the fact that it is optional somehow implies that back vowels can be optionally [-back] (?). Second, the architecture of the vocal tract I am developing here disallows characterizing a sound in terms of the activity of the articulator which does not participate in the constriction.

unified view of the physical reality behind the sonority hierarchy phenomena. We can associate various steps in the sonority scale with varying degrees of air pressure in the cavity behind the constriction, prior to the release. Highly sonorous segments would be associated with small air pressure, and the segments at the opposite end of the scale would be characterized by high air pressure behind the constriction. We could hypothesize that sonority constraints may really be constraints on the air pressure maintenance in the vocal tract: steady decrease or increase may be preferred over the choppy pattern.

1.3 Phonological Motivation for the Constriction Model

On the phonological side, the constriction model draws support from the fact that it is capable of explaining a variety of phonological phenomena which have been left unaccounted for by the earlier models of segment representation.

One of the outstanding problems in phonology are vowel consonant interaction phenomena. These include palatalization of consonants in the environment of /i/ and /e/-like vowels, pharyngealization of consonants in the environment of non-high vowels, palatalization of vowels before consonants with the palatal constriction location, vowel lowering conditioned by uvular, pharyngeal and laryngeal consonants (cf. McCarthy (1989), labialization of consonants by vowels, dissimilatory processes involving consonants and vowels, vowel hardening and consonant softening, etc.

Some of these processes have already received satisfactory accounts; this is true, for instance, about round vowel/labial consonant interaction phenomena, which have been insightfully analyzed by Sagey (1986). Yip (1988), others. Not surprisingly, the language of the phonological representation introduced by Sagey (1986) allows labial consonants and round vowels to share a phonological feature to the exclusion of all other segments.

It is clear that the understanding of vowel/consonant interaction phenomena is limited by the extent to which vowels and consonants are allowed to share phonological features. Since none of the currently available feature classifications provides "equal feature access" to vowels and consonants, none is capable of accounting for these phenomena fully.

Consider, for example the feature system which underlies the characterization of sounds in the International Phonetic Alphabet; this system characterizes consonants strictly in terms of the constriction location features: labial, labiodental, dental, alveolar, palatoalveolar, palatal, velar, uvular, pharyngeal, and laryngeal; and vowels -- strictly in terms of the tongue body features: back, high, low. Obviously, no vowel/consonant interaction processes can be explained in this system.

Next, consider the feature system of Chomsky and Halle (1968): it is based on the assumption that primarily, the moving parts of the vocal tract, not the regions, form the basis of the articulatory features (feature [anterior] is an exception in this system, see the comment below). This view also forms the basis of the proposals in Halle (1983) and Sagey (1986) (I will refer to these proposals as the "articulator model"), in which the concept of the articulator, corresponding to the anatomical organ that executes the constriction, is made explicit and fully developed. While these proposals afford a more uniform view of vowel and consonant phonology, as they represent all segments in terms of articulators, surprisingly, they are not capable of addressing the issues of vowel/consonant interaction, except for the cases in which the two are allowed to share the articulators. However, even in these cases, the explanation is not always available. For example, the velar /k/, owing to its characterization by Sagey as a plain dorsal, has as much in common with the vowels articulated in the velar region as it does with all other vowels (owing to the fact that in Sagey's system all vowels are dorsal).

Interestingly, the SPE model (as well as the Clements/Sagey model which it inspired) does recognize (even if not explicitly) the limited need for the constriction location features. For example, it posits the feature [anterior] in order to account for the phonemic contrasts under the coronal node. There is no correlate of [anterior] other than the constriction location. An unfortunate consequence of making [anterior] a dependant of the Coronal Node (as in Sagey (1986)) is that only the coronal segments can be characterized in terms of this feature. This automatically rules out a possibility of an assimilation account of the palatalization phenomena within the articulator theory: while palatalization is triggered by segments which are dorsal (front vowels), its output are the coronal sounds^{*}.

From a purely phonetic point of view, it is obvious that many examples of vowel/consonant interaction involve processes that are sensitive to the location of the constriction, not to the articulator which executes it (see chapter 3 for such examples). Since the information about the constriction location can be manipulated by phonological rules, it must be stored in the form accessible to such rules, in other words, it must have a mental representation. The constriction model gives mental representation to the constriction location, in the form of Site features, argued for in chapter 3.

Support for the constriction model comes also from the fact that a significant number of phonological contrasts cannot be captured without the Site features. Consider the contrast between the bilabials and labiodentals (/ɸ/ vs. /β/ vs. /v/), utilized in languages like Ewe (Warburton et al. (1968)). Since both classes of sounds are represented with the Labial Articulator in Sagey (1986), and since this articulator does not dominate any constriction location feature on her model, both classes of segments are assumed

^{*} Although, attempts have been made to account for palatalization within the limits imposed by the "articulator" theory. For example, Clements (1976) treats front vowels as coronal, and analyzes palatalization as "coronalization". This account, phrased within the SPE terminology, has been translated into the Clements/Sagey model by Ito and Mester (1989). There are a number of unfortunate consequences of such an analysis, which are discussed in detail in 5.4.

to be non-distinct articulatorily-wise. The SPE-suggested treatment of /ɸ/-/β/ contrast appeals to two features: [strident], and [distributed]. However, phonological evidence suggests that this is not a possible solution: /β/, which according to this treatment is supposed to be [-distributed, +strident] never patterns in the processes in which these features are activated. This is shown in some detail in chapter 6.

On the constriction model, the /ɸ/-/β/ contrast is treated in terms of different Sites: Labial in /ɸ/, and Anterior in /β/.

Maddieson (1988) reports another contrast which the articulator model cannot capture: in a number of Austronesian languages spoken on the islands of Espiritu Santo: Tangoa, Araki, Mafea, Acra, Vao, Mpotovoro, etc., phonemic contrasts obtain between bilabials, dentals (or alveolars), and the sounds articulated with either the tip or the blade of the tongue against the upper lip. It is clear that the feature [anterior], which the articulator model employs in order to account for the phonemic contrasts under the Coronal Node, cannot account for the phonemic contrasts among the coronal sounds in these languages. Instead, what appears to be needed to characterize these contrasts, is the reference to the location of the constriction.

The Dorsal Articulator can execute a constriction at three (possibly four) different locations: against the hard palate, soft palate, and in the pharynx. Among vowels, the resulting contrasts can be handled successfully in terms of [high], [low], and [back] -- features which are independently motivated for the vowels. However, there is at least one contrast among the dorsal consonants which these features definitely cannot handle: it is the contrast between the palatal stop and fronted velar. While few languages have underlying fronted velars in their inventory, most have a process which fronts velars adjacent to front vowels. Often languages that have also palatal stops (Macedonian, Basque), contrast the two sounds before front vowels.

Given the limitations of the articulator model, it can, at best treat both sounds as [-back]. On the constriction model, the palatal stop is a dorsal palatal, and the fronted velar is a [-back] dorsal velar (for a number of arguments to that effect see chapter 6).

Finally, the support for the constriction model comes from the fact that it rules out a number of phonological processes which never occur. Consider this: the articulator model has no intrinsic constraints on how many out of the three articulators can be hooked onto the Place Node at any given point (aside, maybe, from the language-specific constraints on complex segments). Since it specifically predicts the spread of an articulator past any sound that is not specified for that articulator, it allows and predicts, for example, a process which spreads the Coronal Articulator across a vowel (the Dorsal Articulator), onto a Place Node that dominates a bilabial, followed by the delinking of the labial articulator. Basically, it allows an /m/ to /n/ assimilation across a vowel. While the processes of /m/ to /n/ assimilation do exist (and are commonly known under the label of "place assimilations"), they are almost invariably local. Short of stipulation, there seems to be no good way of ruling out a long distance, feature changing spread of coronality, labiality, etc., on the Sagay's model, and, by the same token, no way of explaining why such processes must be local.

On the constriction model, such processes are ruled out by the fact that a well-formed constriction is a function of two variables, the Site and the Articulator. While unspecified representations, with the value for one (or both) variables not entered are allowed (in agreement with most theories of underspecification), a constriction with more than one value for either the Site or the Articulator is ill-formed, and is ruled out under a general assumption that ungrammatical representations are universally blocked (underrivable) at all intermediate levels (for the discussion of this assumption see chapter 7).

One consequence of this is that all spreading of Articulators or Sites to a fully specified constriction node is impossible, both long

distance and locally. Spreading of either the Site or the Articulator onto a constriction will be allowed just in case the representation is not complete for the value of the Site or the Articulator (or both).^{*} In those cases, the focus and the target need not be adjacent on the skeletal tier, unless the process is subject to prosodic constraints. Finally, processes in which all articulatory features are assimilated, are treated as the spread of the Constriction Node. Nothing prevents the spread of this node -- after all, this is the primary source of deriving complex segments.

1.4 The Structure of the Constriction Model

In this section, I discuss the format for the representation of phonological segments within the constriction model. I begin by reviewing the content of the nodes and the features in the segmental tree.

1.4.1 An Overview of Nodes and Features

Following Clements (1985) and Sagay (1986), I assume that all segments are represented with the Root Node, which dominates all other features in the segment. The Root Node is necessary in explaining assimilations which spread the totality of features, as observed, for example, in the compensatory lengthening processes. It directly dominates the degree of closure, air stream, and phonation features. Following Piggott (1987), and McCarthy (1988), I assume

^{*} This could be the case with the so called consonantal harmonies observed in child speech. Apparently, there has been a dissertation out of the University of Illinois, by Cathy Echols, which explores the idea that at early stages, the words are not fully represented in the speech of children, that only the most salient sounds (e.g. in stressed syllables, at the beginning of the word, etc.) are fully represented, and that consonantal spreading might be the means of filling out incomplete representations (I am grateful to Michael Kenstowicz for bringing this to my attention.)

^{*} This is pretty much a hypothesis. An alternative view would be to associate the stricture features with the constriction node. While some complex segments have identical stricture features on all constrictions, there are segments which have consonantal constrictions combined with vocalic ones, as, for example, is the case with palatalized segments. For the time being, I want to treat the question of the location of the stricture features as unresolved; placing them under the Root Node is just a temporary solution.

Pharyngeal is the Site involved in the production of all gutturals: uvulars, pharyngeals and laryngeals. I also assume, that the low vowel *a* involves a pharyngeal constriction*.

Before leaving the topic of the Sites, let us recall that in Wood's (1979, 1982) studies of vowel articulation, which have inspired the treatment of vowels proposed in this thesis, four rather than three basic constriction locations for vowels are proposed: the palatal, palato-velar, upper-pharyngeal and lower-pharyngeal. The difference between Wood's proposal and mine boils down to the presence vs. absence of subdivisions within the pharyngeal region. Again, my treatment draws on the results of McCarthy (1989), which reveal that segments with the pharyngeal constriction pattern together in various phonological processes, and therefore form a natural class. Since, as McCarthy points out, as many as three different articulators may be involved in the production of gutturals, the point of articulation (pharyngeal) is the only candidate for a feature which would capture this property of the gutturals. If so, the source of distinctions among the pharyngeal sounds must not be derived from a different constriction location but from other factors. Later on (in chapter 5) I will argue that different pharyngeal sounds may appear to have constrictions in different areas of the pharynx as a consequence of the fact that they are executed with different articulators.

Articulators map onto the organs capable of performing vertical or horizontal movements. With the exception of the Tongue Root, which I adopt after Ladefoged and Maddieson (1986), and the Glottis, they are exactly the articulators of the Sagey (1986) model, with the names modified so as to avoid confusion with the Sites (the Site names are adjectival, and the Articulator names are nominal). The following is the inventory of the Articulators: Lower Lip (Sagey's Labial Articulator), active in the production of bilabials and

* So far, I have pointed out the Sites for the "extreme" vowels *i*, *u*, and *a*, and left out of the discussion the mid, as well as the "interior" vowels. Later on, I will suggest a treatment of vowels which pretty much derives the remaining qualities from these three basic ones.

that the nasality features too are dominated directly by the Root Node. Finally, the Root Node dominates the Constriction Node(s), the seat of all articulatory features.

The Constriction Node dominates the Site and the Articulator Nodes. I assume that this is the canonical form for the Constriction Node, and that at no point in the derivation are there more than one Articulator or more than one Site under this node. Derivations which violate this condition are universally blocked.*

The concept of the Site corresponds to an earlier concept of the "passive articulator". Sites correspond to the regions in the vocal tract with which the articulators come in contact during speech production. They are "fixed" structures that cannot be otherwise modified, therefore, Sites do not dominate any other features.

The Labial Site maps onto the upper lip: the constriction region in bilabials and linguo-labials (the latter: sounds observed in several Austronesian languages (Maddieson (1988)) which are articulated with the tip or the blade of the tongue). The Anterior Site corresponds to the region which extends from the upper incisors to the alveolar ridge (inclusive); labiodentals as well as all dentals and alveolars involve this Site. The Palatal Site maps onto the hard palate -- the constriction location of the coronal and dorsal palatals, as well as front vowels. The Velar Site maps onto the soft palate which is involved in the production of velar consonants and high back vowels. The Pharyngeal Site maps onto the back wall of the pharynx; following the revealing study of guttural phonology by McCarthy (1989) (discussed in detail in 3.5), I assume that

* While Ideas of this sort are highly speculative, at least at the present stage of our knowledge of genetically conditioned behavior, it is not unreasonable to assume that certain gestures that humans perform are "prewired", that is, genetically encoded. These Ideas have been explored in the context of research on other orally performed gestures, such as chewing, sucking, crying, etc. My way of thinking about the representation of the constriction gesture has been inspired by such Ideas, and particularly by the suggestion made by Perkell (1979), which extends the concept of "preexisting motor circuitry" (p. 368) to speech gestures

labiodentals; Tongue Blade (Sagey's Coronal Articulator), the articulator active in dentals, alveolars, coronal palatals, as well as the linguo-labials; the Tongue Body (Sagey's Dorsal Articulator), the articulator active in dorsal palatals, velar, uvulars, and all non-low vowels; the Tongue Root -- active in the production of the low vowel **a** and the so called "pharyngeals"; the Glottis, the articulator of the glottal stop and the laryngeal fricative **h**.

Articulators capable of assuming distinct, phonologically relevant shapes, are associated with the features which represent these shapes. For example, the Lip dominates the feature [round] which refers to the shape of the lips.

The Tongue Blade dominates the [distributed], the feature which distinguishes lamina. ([+distributed]) and apical ([-distributed]) sounds. I assume that [-distributed] is sufficient for characterizing all apical sounds, whether with a slight raising of the tongue tip, or extreme retroflexion; to my knowledge, no language differentiates between the two varieties for any given Site.

Following the arguments in Levin (1987), I assume that the Blade (the coronal articulator) dominates the feature [lateral], in addition to [distributed].

The Tongue Body dominates the features [high] and [back]. Traditionally, the feature [low] has also been included among the dorsal features. However, since the constriction of the low vowel **a** is produced with the Tongue Root, the feature [low] is no longer needed for the purpose of distinguishing this vowel from the mid vowels*. The status of this feature in the constriction model is discussed in 5.4, along with other tongue body features.

* Later on, I will consider a possibility that languages may have a non-high, non-round, back vowel made with the Tongue Body constriction. I will make a point of showing that such a vowel acts both phonologically and phonetically as [-high].

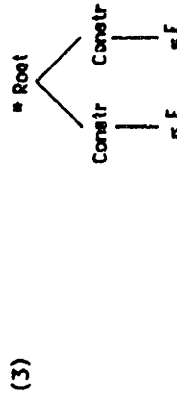
Finally, the Root and the Glottis are not modified by additional features.

1.4.2 The Structure of the Representation: Simple vs. Complex Segments

In the present model, simple segments are represented with one Constriction Node, complex segments with two or more. I assume that there are no structural constraints on the number of Constriction Nodes in a complex segment, and that the existing limitations are most likely acoustically or perceptually conditioned. For example, Ladefoged and Maddieson (1988), show that the number of primary constrictions in a surface complex stop must be no greater than two, as the acoustic cues for an additional constriction would necessarily be lost between the acoustic cues for the onset of one constriction and the release of the second.

The only structural constraint on complex segments is that no Articulator or Site may be involved in more than one constriction in any given segment. This constraint is somewhat reminiscent of Sagey's (1986) prohibition against complex segments in which one articulator executes two constrictions. However, J. Harris (p.c.) has pointed out to me that deriving such a constraint from the sheer impossibility of one object being at two locations (*whir** appears to be the reasoning behind Sagey's proposal) is not necessarily justified. For example, given the size and the strategic location of the dorsum (Tongue Body), it is not obvious why it could not participate in two constrictions (say, palatal and velar) simultaneously. Or, given the fact that both the lower lip and the coronal articulator, can form a constriction in the region of upper incisors (Anterior Site), there should be no technical difficulty for the Anterior Site to be involved in two constrictions, labial and coronal, simultaneously.

Given the fact that no language contrasts sounds solely in terms of such possibilities^{*}, it appears necessary to rule out the phonological combinations of features not on physical, but on some other grounds. I would like to suggest, tentatively, the following constraint:



The constraint in (3) is pretty much a descriptive statement. Hopefully, with a better understanding of phonological features it can be replaced by an explanation.

2. Articulators

Given the results of feature representation research conducted within the articulator model (Steriade (1985), Sagey (1986), Yip (1988), McCarthy (1988), etc.), it may appear somewhat superfluous to argue for the phonological constituency of articulators. To some extent this is true, therefore I shall devote a limited amount of time to this issue, mostly summarizing the arguments that have already been proposed. However, the status of articulators is somewhat different in the present framework, since they are not the sole source of articulatory features (cf. the Site features already present in the system). In order to establish an independent need for the articulator features, it is necessary to prove that there exist phenomena which can be dealt with only in terms of these features.

Therefore, in what follows, I shall concentrate on such phenomena; I shall consider processes which affect either the entire natural classes formed by the sounds sharing the same articulator, or the subsets of these classes defined only in non-articulatory terms. For example, if a language treats in some special way all coronal continuants, but not the stops, we still consider this as evidence for the constituency of the Tongue Blade articulator. On the other hand, processes which involve, say, a palatal subset of the coronal sounds, cannot be considered to support the constituency of the Tongue Blade articulator.

The phonological phenomena that will be used as evidence are the concurrence restrictions on segments which have identical features (best treated in terms of the Obligatory Contour Principle, which prohibits adjacency of identical segments (Lében (1973), McCarthy (1979), McCarthy (1981), McCarthy (1986), Yip (1987), (1988), etc.), and phonological processes which affect, or are triggered by, the natural classes whose existence we are trying to establish.

2.1. Lower Lip

^{*} Before this can be asserted, I would like to address the claim that has been made on several occasions about the palatal sounds in Russian; according to this claim, there is a palatal/palatalized distinction in Russian. This distinction is supposed to account for the contrast between the so called "soft" palatal and the "hard" palatal, cf. Dunetev (1963), Schmalstieg (1964), de Armond (1966), etc. However, it is not necessary to appeal to secondary palatal articulation, in order to express the contrast between the two types of palatals; the "soft" palatal is executed with the tongue blade, while the "hard" palatal involves the tongue tip; the contrast is then between the + and - values of the feature [distributed]. In fact, this is not the only contrast, as the apical fricative is also velarized, as shown on the X-rays, cf. Bruzgunova (1963).

The natural class characterized by this feature comprises segments /p, ɸ, f, m, b, u, ɣ, o, ö/, etc., and other dimensions of these articulations.

Many languages lack labio-dentals, therefore, the class of sounds articulated with the Lower Lip in such languages matches exactly the class of sounds with the Labial constriction site. Even if there exist phenomena in such languages which single out the labial sounds (cf. the co-occurrence restrictions on labials and round vowels in Taiwanese, Lin (1989), labialization of the epenthetic vowel in the environment of labials in Chukchee (Sagey (1986), etc.), they cannot be analyzed unambiguously in terms of a Site or an Articulator feature. Therefore, they do not provide unambiguous support for the Articulator feature Lower Lip, or for the Site feature Labial in a system that contains both.

Even those languages which do have labiodentals do not always provide an ideal ground for testing either of these features, as the presence of labiodentals in the surface inventory of a language does not necessarily guarantee that they are present in the underlying inventory. Only languages which display surface bilabial and labiodental fricatives cannot be doubted to have underlying labio-dentals. In languages which do not display such a contrast, it may often be the case that labiodentals serve as the surface manifestation of bilabials: bilabial fricatives have much less noise than labiodentals; therefore, for perceptual reasons, labiodentals might be preferred over bilabials in surface representation. This issue is discussed in more detail in 3.2.

I have been unable to find an example of a language which would contrast the labial and labiodental sounds, and, in addition, would display phenomena in which the two types of sounds would act like a natural class. However, I know of at least one example of a language in which the interaction between labial sounds can be analyzed only in terms of the Lower Lip articulator. This language is Sudanese Arabic.

2.1.1 Sudanese Arabic

In Sudanese Colloquial Arabic* (Hamid (1984), after Kenstowicz (1989)), the following processes take place: Voicing Assimilates and Articulatory Assimilation. The first rule assimilates the voicing of word-final obstruents to the voicing of the obstruent of the following word. The second rule assimilates word-final obstruents to all articulatory features of a following obstruent, if both segments share the same articulator. In addition, stops assimilate in continuancy to fricatives (but not vice versa, M. Kenstowicz p.c.). I begin by presenting the entire paradigm now, and later on, I repeat the portions of the data relevant to each articulator:

(4)(a)	kitaab 'book'		
	kitaal[ɾ] Fathl		
	kitaal[p] Saamiya		
	kitaal[p] Xallid		
(b)	bit 'girl'		
	bit[t] farid	ʔalbil[z] zaakaral	'the girl studied'
	bit[t] hasan	ʔalbil[ʃ] ʃaafat	'the girl saw'
	bit[s] saamiya	ʔalbil[d] ʃirfat	'the girl knew'
	bit[ʃ] ʃalal	bit[ʃ] ʃomilla	'beautiful girl'
		bit[d] ʃarliba	'strange girl'
	balad 'country'		
	balat[t] farid	ʔalbalal[d] gaddam	'the country offered'
	balal[d] ʃaasim	ʔalbalal[ʃ] ʃaarak	'the country shared'
	balal[s] samir	ʔalbalal[z] zaraʃ	'the country sowed'
	balal[ʃ] ʃalal		
(c)	semek 'fish'		
	samak[k] fathl	vs.	samak[x] xallid

* I am grateful to Michael Kenstowicz for making these data available to me.

samə[k] samɪr samə[ɣ] ɣarɪb

samə[k] ʒarɪr

sawwʊʒəg 'driver'

sawwə[k] fərɪd vs. sawwə[ɣ] ʒayɪd 'good driver'
 sawwə[k] həsən sawwə[ɣ] ɣarɪb 'strange driver'
 sawwə[ɣ] xəlɪd sawwə[k] kəsɪlən 'lazy driver'

The data relevant for the discussion of labials, shown in (4a) demonstrate that while /b/ assimilates in voicing to any obstruent, it assimilates in the remaining features only to /l/.

The paradigm in (4) may be interpreted as follows: there is an OCP triggered deletion of the Constriction Node in the first of the consonants, followed by the spread of the Constriction Node of the consonant on the right.

2.2 Tongue Blade

Let us now turn to phonological phenomena which support the constituency of the Tongue Blade (coronal) Articulator. This class of sounds includes, among others, the following: t, ʈ, d, ɖ, s, ʃ, z, ʒ, ʁ, ʎ, n, l, r, ʂ, ʐ, ʑ, ʒ, ʒ̥, ʒ̥̥, etc., as well as the complex segments involving these articulations (e.g., ʑʷ, ʐʷ, ʑʷ, etc.). I am assuming here that no vowels involve the Tongue Blade articulator. I discuss this issue in more detail in 5.4.3.

One form of evidence for the existence of the articulator node Tongue Blade is the existence of features that are universally dependent on this articulator. Steriade (1985), argues for the constituency of the coronal articulator (as opposed to the feature [coronal]) on the basis of the need for hierarchy within that node: she points out that features such as [lateral] and [distributed], which may only be used distinctively to characterize the coronal sounds, and which are active phonologically only within the coronal class, are best treated as the dependants, not the sisters of the coronal node.

Other forms of evidence for the coronal articulator come from the phonological phenomena in which the sounds articulated with the tongue blade/tip form a natural class. I now turn to the discussion of such phenomena.

2.2.1 Sudanese Arabic

Since the Sudanese Arabic has both anterior (t, d, s, z, ʈ, ɖ, ʃ, ʒ) and palatal (ʂ, ʐ) coronals, the data to be presented provide a particularly convincing argument for the constituency of the Tongue Blade articulator. All coronals pattern alike in the Articulatory Assimilation:

(5)	bɪt	'girl'	
	bɪtɪ	fərɪd	ʔalbɪ[z] zaakarət 'the girl studied'
	bɪtɪ	həsən	ʔalbɪ[ʂ] ʂaʔət 'the girl saw'
	bɪsɪ	səʔmya	ʔalbɪ[d] ʕɪrɪt 'the girl knew'
	bɪʂ	ʂələ	bɪʂ ʂəmɪlɪə 'beautiful girl'
			bɪd ɣərɪbə 'strange girl'
	bələd	'country'	
	bələtɪ	fərɪd	ʔalbələ[d] gəddəm 'the country cifered'
	bələd	gəssɪm	ʔalbələʂ ʂaʔək 'the country shared'
	bələsɪ	səmɪr	ʔalbələ[z] zərə 'the country sowed'
	bələʔ	ʔalaal	

In (5), the anterior consonant assimilates in point of articulation and continuancy to /s/, /ʂ/, /ʑ/, /z/, /ʒ/ -- i.e. coronal consonants, but not to /t/, /ɖ/ or /ʕ/. the labial, velar and pharyngeal consonant respectively.

2.2.2 Classical Arabic

* The palatal ʂ has been argued to be an underlying g in Arabic dialects, cf. McCarthy (1989). However, at the level of representation at which Articulatory Assimilation operates in the Sudanese dialect, ʂ appears to pattern with the coronals.

Kenstowicz and Kisseberth (1979) report the following phenomenon as evidence for the SPE feature [coronal]: "in Classical Arabic, the /l/ of the definite article /ʔal/ completely assimilates to a following dental or palatal consonant, but remains unchanged before labials, velars, uvulars, pharyngeals and laryngeals" (p. 249). They present the following data:

(6)	ʔal baab	'the door'	vs.	ʔat tax	'the bed'
	ʔal faras	'the horse'		ʔad deer	'the house'
	ʔal kalb	'the dog'		ʔas sanduug	'the box'
	ʔal xaaltem	'the ring'		ʔaz zayt	'the oil'
	ʔal qalb	'the heart'		ʔar raʔul	'the man'
	ʔal harb	'the war'		ʔan naas	'the people'
	ʔal ʔab	'the father'		ʔaʕ ʕams	'the sun'

Given that phonological processes affect natural classes of sounds, the phenomenon illustrated in (6) constitutes evidence for the feature Tongue Blade Articulator, since it takes place only when /l/ is adjacent to a coronal segment.

2.3 Tongue Body

I now turn to the arguments for the feature Tongue Body articulator. Other than in vocoids, this articulator is active in the production of ʕ, ʔ, ɕ, ʑ (voiceless and voiced dorsal-palatal fricatives and stops respectively), k, g, x, ɣ, ŋ (velars) and q, ɢ, ʁ, ʁ̥, ʁ̥̥ (uvulars)*. As for the vowels and glides, I assume that Tongue Body is an active articulator in all of them, except for the "low" vowel /a/, which I assume to be articulated with the Tongue Root (see section 5.4.4).

One way to argue for the phonological constituency of the Tongue Body, is to appeal to the fact there exist features which are universally associated with what we consider as the dorsal

* Following McCarthy (1989), I assume that uvulars are complex segments involving both velar and pharyngeal constriction locations. The only difference between McCarthy's treatment of uvulars and mine follows from different assumptions about the nature of phonological representations.

segments (following the line of argument for the constituency of the coronal articulator proposed by Steriade (1986)).

It would make very little sense to characterize sounds such as /p/, /t/, or /t̪/ in terms of features [high] or [back]. On the other hand, there is massive evidence for the existence of such features in the phonology of sounds in whose production the tongue body is (distinctively) active. Just to give a few examples -- Calabrese (1985) analyzes the process of metaphony in Salentino, a southern Italian dialect, which raises a stressed vowel followed by a high vowel in an adjacent syllable. This harmony is blocked by a segment which Calabrese transcribes as /k'/, and calls a "palatal occlusive" (p. 17). Below are a handful of examples in which the harmony has applied, and a few cases in which the intervening "k'" inhibits the process:

(7)(a) e --> i / _____ + high
+ stress

sing: -ə plur: -i (word-final mid vowels are raised)

paráti	par'ti	'wall(s)'
reéti	r'f'ti	'net(s)'
mési	m'f'si	'month(s)'

(b) o --> u / _____ + high
+ stress

crúci	crúci	'cross(es)'
nóci	núci	'nut(s)'
stašóni	stašúni	'season(s)'

(c) the blocking effect:

vekk'u	'old'
supérk'u	'outrage'

* See the discussion of /t̪/ in 3.3

cupérk'u 'cover'

The only way to understand the blocking effect in (7a), is to assume that the segment "k", intervening between the trigger (the high vowel) and the target (the stressed vowel) shares with the trigger the spreading feature [high]. As to the nature of the blocking segment -- based on Calabrese's description which characterizes it as a complex segment composed of a velar and a front glide -- one can hypothesize that it is, most likely, a front velar redundantly specified as [+high] on the dorsal node. Coming to the point of this presentation, the Salentino facts show that the feature [+high] associates with a non-low vowel and a velar consonant -- segments articulated with the Tongue Body. It does not associate with any segment in the language which is not articulated with Tongue Body. The only way of capturing this fact in a simple way is to have a theory with a phonological constituent Tongue Body, on which the feature [high] depends.

A different example in which it is convenient to assume that velars, which are inherently dorsal consonants, may be redundantly specified as [+high], is found in Cantonese, where a velar consonant is not a "low-d" in the rhyme of a syllable whose nucleus is a high vowel.

In Cantonese, something as common as the assimilation of a velar to the language body position of an adjacent vowel (discussed in detail in chapter 4) provides evidence for an intimate relationship between the height and the backness features on the one hand, and the Tongue Body Articulator on the other; after all, non-dorsal segments are not typically affected by the frontness or backness of an adjacent vowel; mutual influences in terms of these features are possible only among the dorsal segments.

Let us now turn to phonological phenomena which group dorsal consonants into natural classes. Among consonants, non-velar dorsals are fairly uncommon, which makes the task of arguing for the Tongue Body as a phonological entity distinct from the Velar

Site less than easy on the consonantal material. Phenomena which single out vowels and velar consonants are probably even less common. In fact I don't know of any. Here, I continue the discussion with the presentation of Articulatory Assimilation of the word-final dorsals in Sudanese Arabic, on the assumption that this process is across the board articulator-sensitive.

2.3.1 Sudanese Arabic

The only dorsal consonants in Sudanese Arabic are velars. The Articulatory Assimilation affects them as follows:

(8)	samak	'fish'		
	samak[k]	fəthi	vs.	samak[x] xaalid
	samak[k]	samlir		samak[y] ʔarib
	samak[k]	ʃarir		
	sawwag	'driver'		
	saww[ak]	fariid	vs.	saw wae[g] ʒayyid 'good driver'
	saww[ak]	hasan		saw wae[y] ʔarib 'strange driver'
	sawwae[x]	xalid		saw wae[k] kaslaen 'lazy driver'

I believe that interpreting the above data together with the rest of the paradigm presented in (4) (namely as a reflex of the Articulatory Assimilation) is well justified. The generality of the process suggests that this is the correct approach (otherwise the language would have to have two, very similar, but structurally unrelated processes). Also, the absence of this phenomenon under the constriction location (Site) identity (pharyngeals and laryngeals are not affected by Articulatory Assimilation) points to the same conclusion.

3. Sites

In this chapter I consider evidence for the phonological constituency of the Site features: Labial, Anterior, Palatal, Velar, Pharyngeal. I follow the format of the argument adopted in the preceding chapter, and argue for the Site features on the basis of the phenomena which can be explained only in terms of these features.

3.1 Labial Site

The sounds which are characterized by this feature include the following: p, b, m (linguo-labials), p, b, m, ɸ, β, m, ɸ, β, k, ʔ, tʰ, pʰ, u, o, ü, ö, etc. At present, I do not know of any phonological phenomena in the languages which have linguo-labials in their inventories, which would group bilabials and linguo-labials into a natural class. Therefore, the only possible way of arguing for the feature Labial Site, is on the basis of the phenomena which single out bilabial sounds in languages which have both bilabials and labiodentals in their inventories: Since in the constriction model labiodentals are represented with the Lower Lip constriction at the Anterior Site, they contrast minimally with the bilabials, which are represented with the Lower Lip constriction at the Labial Site. I argue that the process of labial dissimilation in Venda, Zulu and other Bantu languages (Pedi, Tswana, etc.) is an example of a process which distinguishes among segments on the basis of their Site specification.

3.1.1 Velarization in Venda

Venda (segment inventory according to Doke (1954)): l, t, u, o, ɐ, s, o, ɔ, ɛ, p, pʰ, b, ɸb, m, ɸ, β, f, v, pf, bv, ɸbv, tʰ, d, ɳd, n, l, tʰ, ɸ, d, ɳd, tʰ, tsʰ, dz, ɳdz, ɳ, f, s, z, l, sʰ, zʰ, tsʰ, tsʰ, dzʰ, ɳdzʰ, ɳ, ʒ, ɳ, ɳ, dzʰ, ɳ, kʰ, g, ɳg, w, h) has a dissimilatory process

* There is a practical explanation for this: the existence of linguo-labials has been confirmed only recently (cf. Maddieson (1987)); naturally, languages which are said to have these sounds, are poorly described in the linguistic literature: we simply do not know what their phonology is

affecting the stem-final bilabials (ɸ, β, m, pʰ, p, b) before the passive suffix /-wa/, which results in a velarization of either the first of the second segment. The following alternations are observed: bilabial fricatives turn into velars: ɸw --> xw; βw --> ɣw; when bilabial stops are combined with /w/, the /w/ turns into a velar fricative: pʰw --> pʰx; pw --> pɣ; bw --> bɣ; nasal /m/ may pattern with either fricatives or stops: mw --> ɳw (mɳ) (Doke (1954)). The interaction of /-wa/ with stem-final consonants is illustrated below:

(9)(a)	βoɸ + wa --> βoxwa/βoɸtwa	'be tied'
	dɪβ + wa --> dɪɣwa/dɪβtwa	'be known'
	nɔp + wa --> nɔpxa/nɔptwa	'be switched'
	kʰopʰ + wa --> kʰopʰxa/kʰopʰtwa	'be broken off cob'
	bɛb + wa --> bɛbɣa/bɛbtwa	'be begotten'
	lum + wa --> lumɣa/lumwa	'be bitten'
(b)	fun + wa --> funwa/funtwa	'be loved'
	rɛnd + wa --> rɛndwa/rɛndtwa	'be praised'

According to Doke (1954), p. 157, only bilabials are affected. This is important, in view of the fact that there are labiodental fricatives in Venda.

I would like to suggest the following analysis of the velarization facts: Venda has a constraint on sequences of segments that have a labial point of articulation. This might be interpreted as an OCP effect applying at the Labial Site tier. When a bilabial stop becomes adjacent to a round glide, the labial component of the glide is delinked. The resulting segment is a velar glide; since such a segment does not exist in the underlying inventory of Venda (see above), it is reanalyzed as a velar fricative, which assimilates in voicing to the preceding segment. It appears that in the case of

* Velarization also occurs when the glottal 'fricative' h is followed by a round glide, e.g. Puleh + wa --> Puleɣwa 'to be killed'. I assume that h is really an approximant, just like the glide, and what appears as velarization, really serves the purpose of strengthening the first segment, with the velar component being a result of either a default rule or spreading from the glide.

bilabial fricatives followed by a round glide, the labial component is deleted in the fricative, and the glide remains intact. There are two ways of interpreting the velar component in the fricative: either it is inserted by a default rule, or it spreads from the following glide. Again, it is outside the scope of the present discussion to decide what the actual mechanism might be.

The difference in the behavior of fricatives and stops before a round glide can be interpreted as due to a constraint against sequences of obstruent fricatives in Venda; if the derivation proceeded in the same fashion for fricatives as it does for the stops, the output of the process would have been a sequence of /ʃ/ (/β/) and /x/ (/ɣ/). Apparently, such sequences are not found in Venda.

The above analysis crucially depends on the existence of an articulatory feature by which the bilabial and labiodental fricatives may differ. I am suggesting that such a feature is the Labial Site which corresponds to the labial constriction location. Without this feature, phonological interpretation of the velarization facts in Venda is not available.

3.1.2 Palatalization of Bilabials in Zulu

Palatalization of bilabials is a wide spread phenomenon in Southern Bantu languages. The fact that it occurs most commonly when a bilabial consonant becomes adjacent to a round glide (either as a result of affixation or a phonological process), suggests an analysis in terms of dissimilation. Of interest here is the fact that labiodentals are never affected by the process. This suggests that the dissimilatory effect is not triggered by the same articulator, but instead, by the feature which is based on the same constriction location -- the feature Labial Site.

I discuss the palatalization of bilabials on the material from Zulu (Doke (1926, 1927), Meinhof (1932)), and, whenever necessary, contrast the facts of Zulu with those of Tswana (Stahlke (1976), Herbert (1977)) and Venda (Ziervogel (1961), Meinhof (1932)).

3.1.2.1 In Zulu (segment inventory (Doke (1926)): consonants: p^h, b, f, v, m, ɓ, p^ʰ, t^h, d, ts^ʰ, dz, s, z, n, l, r, ɓ, t, ɕ, ɕ^ʰ, dʒ, ʒ, ɲ, k, k^h, g, x, ŋ, h, ɦ, ɬ, ɬ^h, ɮ, ɮ^h, ʋ^h, ʃ, ʃ^h, ʒ^h, ʒ, ʒ^h, ʒ^ʰ, ʒ^ʰ; vowels: i, u, e, ɔ, plus the same, series with length), bilabials are palatalized in a number of morphological environments. The following examples illustrate the behavior of stem-final bilabials before the passive suffix /-wa/:

- (10)(a) -tú:p^h + wə --> -tú:šwə^h 'be teased'
 -ɓú:p^h + wə --> -ɓú:šwə^h 'be tied'
- (b) -bú:b + wə --> (kwə:)(ʔ) -bú:šwə^h derivative of 'die'
 -bá:b + wə --> -bá:šwə^h 'be trapped'
- (c) -tú:ɓ + wə --> -tú:ɕ^hwə^h 'be written'
 -tá:ɓ + wə --> -tá:ɕ^hwə^h 'be stabbed'
- (d) -t^hú:m + wə --> -t^hú:ɲwə^h 'be sent'
 -lú:m + wə --> -lú:ɲwə^h 'be bitten'

Examples below show that no other segments are palatalized before /-wa/:

- (11) -ɓon + wə --> -ɓonwə 'be seen'
 -t^hand + wə --> -t^handwə 'be loved'
 -t^handis + wə --> -t^handiswə 'made to love'
 -t^handəl + wə --> -t^handəlwə 'be loved for'
 -ɓon + wə --> ɓonwə 'be praised'

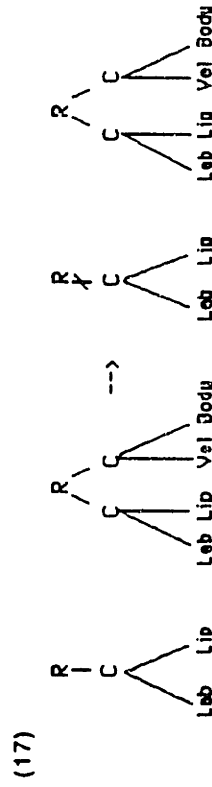
Doke (1926), p. 139-140 emphasizes that only bilabials are palatalized in the context of /-wa/. While Doke himself gives no examples of passivized verbs ending in a labiodental, the fact that the labiodentals are indeed unaffected in the presence of the passive

* Neither Doke nor Meinhof consider the postconsonantal glide as labialization on the consonant. I assume that consonant-glide onsets are allowed by the syllable structure of Zulu. Later on, arguments will be provided to show that at least at the point when palatalization applies, *w* is a segment separate from the stem-final consonant. Only this much is needed for the analysis of the Zulu facts to be presented.

Finally, to complete the locative paradigm, no palatalization takes place if labials are not followed by a round vowel:

- (16) e + impl + inl --> empInl 'army'
 e + Intəfə + inl --> entəfənl 'hill'
 e + InsImbɪ + inl --> ensImbInl 'metal'

3.1.2.2 I would like to suggest the following analysis of the palatalization facts presented above: There are cooccurrence restrictions in Zulu which prohibit sequences of segments with a constriction at the Labial Site. This restriction may be interpreted as an OCP effect applying at the Labial Site tier. When a disallowed sequence arises in the formation of the Passive, the labial constriction of the first segment is delinked. Let us represent this process as follows:



(R = Root Node; C = Constriction Node; Lab = Labial Site; Lip = Lower Lip Articulator; Vel = Velar Site; Body = Tongue Body Articulator)

I assume that palatal constriction is inserted either by default, or by a rule, but since the exact mechanism of that process is not relevant to the present discussion, I do not pursue this issue.

The above analysis does not extend automatically to the data involving the locative morpheme. First, observe that the nouns in which the palatalization of bilabials takes place when they are suffixed with /-ini/, contain the allegedly disallowed sequence in the underlying (and surface) representation. The question arises as to why forms like /sɪtʃɔ:60/ 'friend' are allowed to surface, but

suffix is confirmed by the native speaker of the language (I am grateful to Michael Kenstowicz for making these data available to me):

- (12) ukuxova 'to knead' ukuxovwa/ukuxoviwa 'it is kneaded'
 ukucofa 'to press' kujacofwa/kujacofiwa 'it is pressed'
 ukudlokove 'to shake' kujedlokovwa/kujedlokoviwa 'it is shaken'
 ukungweva 'to ege' kujangwevwa/kujangweviwa 'it is eged'

Another environment in which bilabials are palatalized, involves the locative morpheme /e-...-ini/: here, a bilabial must be followed by a stem-final /w/ or /o/ in order to undergo the rule:

- (13) e + ʃsɪfɔ:pʰo + inl --> ʃsɪfɔ:ʃe:nl 'grass rope'
 e + u:Cu:bu + inl --> u:Cu:ʃ:nl 'mealie-meal water'
 e + ʃsɪfɔ:60 + inl --> ʃsɪfɔ:ʃe:nl 'friend'
 e + ʊmɪD:m0 + inl --> ʊmɪDpɛ:nl 'mouth'

(Note the disappearance of the labial element from both vowel and a consonant in the surface forms.)

No other consonant becomes palatalized in this environment:

- (14) e + i:səŋo + inl --> esəŋwɛnt 'gateway'
 e + u:kʰezɔ + inl --> o:kʰezwɛnt 'spoon'
 e + i:zuɬu + inl --> ezulwɪnl 'sky'

Particularly, the labiodentals are not palatalized under these circumstances. However, they do not behave exactly like non-labials in (11), as two surface forms are possible:

- (15) e + f:mbvu + inl --> embvɪnl or embvɪwɪnl 'sheep'
 e + ɪsɪ:fɔ + inl --> esɪfɛ:nl or esɪfɔe:nl 'disease'
 e + f:fu + inl --> effɪnl or effɪwɪnl 'cloud'

* ɔa is a diphthong.

their suffixed counterparts are not. I would like to suggest the following explanation: the rule responsible for the deletion of the labial node of the consonant applies in derived environments only. In /i s i t ŋ : 60/, the sequence of bilabials exists in the underlying representation. In /e s i t ŋ c é n i/, I assume that since vowel sequences are not allowed in Zulu, the final vowel of the verb stem is delinked when followed by the vowel of the suffix. This creates an input to a syllabification process which resyllabifies a round vowel as an onset, together with the preceding consonant. The data involving the suffix /-wa/ show that such inputs are syllabified only if they do not violate the prohibition against adjacent bilabials. Otherwise, the first bilabial dissimilates to a palatal-coronal.

Let us now consider the data in (11) and (14-16). These examples, show that an analysis which attributes palatalization of the labials to the presence of an underlying palatal segment in /-wa/, or the overt vowel /i/ in the locative, is not possible.

However, an analysis which attributes the palatalization of labials before the passive suffix /-wa/ to an underlying palatal segment has, in fact, been proposed by Khumalo (1987). On the basis of the forms in which the passive suffix is preceded by /i/ (e.g., when following monosyllabic verb stems: uku: + p^ha + wa --> uku:p^hiwa 'be given'), Khumalo analyzes /-wa/ as having an underlying form /-iwa/, and derives the forms in (10) via a process that converts /i/ to /j/, which in turn palatalizes the labials. Khumalo treats palatalization of labials in the locative as a result of a dissimilatory process; first, the rounded vowel following the labial turns into a round glide; then Labial Dissimilation applies to turn this glide into /j/; this is followed by the palatalization of the labial by the palatal glide.

This analysis has one obvious advantage over the treatment I am proposing, namely, it can account in simple terms for the fact that in the locative, but not in the passive, the labial component of the trigger vowel completely disappears in surface representation. Its disadvantage, however, is that it wrongly predicts the

contracted variant of the passive suffix to trigger the palatalization of non-labials as well.

This point has been raised by Herbert (1977), in his discussion of the analysis of Tswana, another Southern Bantu language, by Stahke (1976). Stahke too capitalizes on the fact that the passive suffix surfaces in some forms as /-iwa/; he suggests the process of segmental fusion of /i/ and the bilabial in forms which do not display /i/ on surface. Herbert (1977) points out that in the cases in which palatalization can be attributed to a palatal element (namely, before the diminutive suffix /-ana/), labials are not the only segments that are affected. It is difficult not to agree with Herbert's point, which also applies straightforwardly to Zulu (see the comment about palatalization in the diminutive below).

Conceivably, Khumalo's analysis of the locative could be adopted without his treatment of the passive; particularly if his suggestion that the phenomena observed in the locative are morphologically circumscribed is followed. Note that this analysis must also be expressed in terms of the OCP triggered by the identical Sites, not Articulators.

As for the presence of /i/ in some forms with the passive suffix -- one can hypothesize that it is an epenthetic vowel, used in Tswana as an optional means of preventing the creation of consonant clusters, and in Zulu, as a means of meeting the metrical requirements of the suffix.

The last environment in which palatalization of labials takes place involves the diminutive suffix /-ana/ (/--ane/). In this case, however, the quality of the vowel that follows a bilabial is not relevant; also, bilabials are not the only palatalized segments: optionally, this process affects the alveolar plosives. These two facts separate the phenomenon of palatalization in the diminutive from the cases presented above. We shall return to this phenomenon

* That suffixes do have such requirements, has been shown convincingly by McCarthy and Prince (1987).

when we discuss palatalization processes triggered by palatal vowels.

The analyses of (10) and (13) proposed above capture what these data have in common, and explains the contrast between the behavior of bilabials vs. other consonants before round vowels. Most importantly, it explains the absence of the dissimilatory effect with the labiodentals: since in the model I am proposing the labiodentals are produced with a constriction at the Anterior Site, they are not sensitive to the conditions against adjacent bilabials.

Such analyses are not available within a framework which does not recognize the phonological constituency of point of articulation features, and, in this case, the feature Labial Site (or an equivalent). If this analysis should turn out to be the only way of treating the facts of Zulu in phonological terms, it would constitute an argument for including the point of articulation feature Labial Site among the phonological features. So far however, all I have established is that this is a plausible interpretation of the Zulu facts: in order to promote it to an argument for the feature Labial Site, it is necessary to show that no other treatment of these facts in phonological terms is available.

To this end, I will present arguments again, an interpretation of the Zulu facts in terms of a feature resolution in a disallowed complex segment, as well as an interpretation which would attribute the contrast in the behavior of bilabials and labiodentals to some arbitrary feature, e.g., [continuant], by comparing the facts of Zulu with those of Tswana, in which labial fricatives are bilabial, and subject to dissimilation.

Finally, I will show that the proposed treatment of Zulu is compatible with the assumptions I make about the underlying representation of labiodentals; in 3.2.3, I propose that if phonology of a language fails to treat labiodentals as anterior, and the language lacks a surface contrast among the labials sounds, the surface labiodentals in such a language should be treated as

underlyingly Labial, unless the phonological evidence points otherwise.

Zulu belongs among the majority of world languages which lack the bilabial-labiodental contrast; given the assumption stated above, Zulu labiodentals are the prime candidates for being analyzed as underlyingly represented with the Labial Site. In order to be able to treat them as underlyingly Anterior, I have to find evidence that the phonology of the language treats them as such.

I will present two arguments to this effect: the first argument will be based on the strength of the comparative reconstruction analysis of the rise of labiodentals in Southern Bantu. I will show that labiodentals in the ancestor language of Zulu arose while the Ur-Bantu bilabials were still in its inventory, and when the dissimilation of bilabials has already been a part of the Southern Bantu phonology. Given the assumption that in a language that also contains bilabials, labiodentals are represented with the Lower Lip constriction at the Anterior Site, I will be able to conclude that the labiodentals were originally conceived as Anterior-Lower Lip, and treated as such by the dissimilation process. The second argument for the "anteriority" of labiodentals will be based on their patterning with the anterior coronals in the process of palatalization in the diminutive.

3.1.2.3 A conceivable way of interpreting the data in (10) and (13), is to consider the palatalization effect as a repair strategy (cf. Calabrese (1988)), applied to a segment that has been created during the derivation -- say, a rounded labial. Presumably, in such a case, any feature by which *q* and *//* differ could be used to designate the class of bilabials as segments that are incompatible with rounding. For example, a grammar of a language could plausibly contain a statement such as "[continuant, labial, +round]. I argue against such an analysis on the basis of the data which involve verbs combined with applied or causative, in addition to the passive suffix, which

reveal that dissimilation of the first labial takes place before the merger of segments occurs (if at all). This is shown in (18) below:

- (18) -bop^h + El + wə → -bōšÉ:lwa 'be tied for'
 -bub + Is + wə → -bušf:swa 'be killed for'
 -lum + IsIs + wə → -lumsf:swa 'to be bitten hard'

Next, compare the forms in (18) with the ones below, which do not involve the passive suffix:

- (19) -bop^h + el → -bop^hÉ:lə 'tied for'
 -bub + Is → -bubf:Isə 'killed for'
 -lum + IsIs → -lumsf:sa 'bite hard'

The data in (18) show that the palatalization effect persists in the forms suffixed with /-wa/, even when /-wa/ is no longer adjacent to the verb stem. The comparison between the forms in (18) and (19) reveals that this effect is in no way related to the front vowel of either /-is/, /-el/, or /-isis/.

I want to suggest an analysis of the data in (18) and (19) whose chief component is the assumption that morphemes may attach directly to a root, even if other affixes are already attached to the same edge. [Notice that an analysis based on the idea that dissimilation can affect segments "long distance", skipping the intervening morphemes, because they lack bilabials, is not possible: examples such as /bɒnwə/ (not *ʔɒnwə) 'be seen' show that only the affixal material is invisible to this process. Also, the dissimilation effect does not operate long distance across the epenthetic vowel /i/. cf. uku: + p^hə + wə → ukup^hi:wə, which proves the same.

* The reason for this uncertainty about the phonetic status of consonant-glide sequences is the following: on one hand, neither Doke nor Hiehnor treat these sequences as anything but clusters; on the other hand, there is a considerable linguistic tradition of assuming that at least on surface, Bantu languages have a simple CV syllable structure. Since from the point of view of the analysis adopted here it does not matter what status these sequences have, I do not attempt to resolve this issue.

* The order in which the morphemes appear in (18) does not imply the order of derivation; see the discussion below.

* I owe this point to Ken Hale.

The idea that affixes might be prespecified in terms of targets to which they are allowed to attach, has originally been proposed by McCarthy and Prince (1987) in their work on reduplication. McCarthy and Prince have observed that the so called "infixes" appear to attach to a stem after "skipping" a predictable amount of phonological material (usually definable in prosodic terms), or else, attach to a target that represents a prosodic unit. An idea similar in spirit, has been developed in Aronoff (1987), who allows affixation processes called "head operations", whereby affixes may attach to morphologically specified targets. In general, such operations can pick out morphemes which head the words for the purposes of morphological derivation.

Applied to the data in (18), the concept of targeted derivations allows us to understand why the passive suffix /-wa/ triggers dissimilation in a stem final labial despite the appearance of being separated from it by other morphemes: suffixation of /-wa/ precedes any other suffixation; /-isa/, /-ela/, etc., attach to the head of the construction -- the root.

One consequence of this analysis is that it rules out a possibility of interpreting the palatalization of labials before /-wa/ as a result of feature rearrangement in a complex segment: since there are good reasons for assuming that in a complex segment, articulations are phonologically simultaneous, and not linearly ordered (cf. Sagey (1986)), we cannot allow morphological processes capable of separating such articulations.

3.1.2.4 Let us now turn to the facts of Tswana (segment inventory (Cole (1955)): p^h, m, b, ɸ, t, t^h, n, r, l, ʔ, ts, tsh, ʃ, ʒ, č, č^h, ɲ, dʒ, k, ŋ, ɣ, h; i, u, e, ε, o, ɔ, ɔ) for evidence that the palatalization process, which Tswana shares with Zulu, is in no way related to the [continuity] contrast between bilabials and labiodentals. An analysis that would appeal to this feature is not very plausible, and I doubt if anyone would actually consider it; in this sense, bringing in the data from Tswana may seem unnecessary. However, there is an additional advantage in comparing Tswana and Zulu: their parent

languages developed labial fricatives after they acquired the palatalization process; but when the parent language of Zulu was developing labiodentals (see paragraph 3.1.2.4 below), the parent language of Tswana acquired bilabials.

The analysis of the Zulu facts I am proposing predicts that since the process of palatalization is triggered by the OCP effect applying at the Labial Site tier, it should affect the bilabial fricatives of Tswana. This indeed is the case, as shown by the following examples:

(20)(a)	-bop + wa --> -bočwa/-bopɬwa	'be moulded'
	-gop + wa --> -gečwa/-gepɬwa	'be plundered'
	-tɬabe + wa --> -tɬačwa/-tɬabɬwa	'be stabbed'
	-rɔb + wa --> -rɔčwa/-rɔbɬwa	'be broken'
	-bɔɸ + wa --> -bɔšwa/-bɔɸɬwa	'be bound'
	-leɸ + wa --> -lešwa/-leɸɬwa	'be paid'
(b)	-bɔn + wa --> -bɔnwa/-bɔnɬwa	'be seen'
	-reɸ + wa --> -reɬwa/-reɬɬwa	'be loved'
	-roɸ + wa --> -rokwə/-rokiwa	'be sewn'

Examples above show that just as in Zulu, only labials are palatalized before the passive suffix /-wa/ in Tswana (cf. the forms in (20b)). The stems in the last two examples in (20a) contain a bilabial /ɸ/; in the passivized forms of these verbs, /ɸ/ converts to /š/. Thus the data from Tswana reveal that first, continuancy has nothing to do with the palatalization phenomenon; second, palatalization, even though dating back to the times which preceded the rise of bilabial fricatives in Tswana, has all the earmarks of a phonological rule which affects all sounds that meet its structural description.

3.1.2.5 Even though Zulu does not have a contrast bilabial-labiodental, a reasonable case can be made for the "anteriority" of /ɸ/ on the basis of the following: According to Meinhof (1932) p.27, the majority of Southern Bantu languages have experienced a process

whereby the Ur-Bantu obstruents have turned into labial fricatives before the tense vowel /u/ (among the exceptions are, e.g., Pedi, Tswana, etc.). These fricatives must have arisen as labiodentals, because the process which created them had been taking place while the Ur-Bantu fricative ɸ was still a part of the inventory; it is possible to assume that the phonetic change affecting /ɸ/ was a later development for the simple reason that it has taken different routes in different languages, giving rise to either /w/, (Swahili, Meinhof p. 32), /b/ (Kongo, Meinhof p. 156), or /ɓ/ (Duala, Zulu, Konde, Meinhof p. 32). Also, in some languages, the newly created labiodentals did not suppress the bilabial fricatives; for example in Venda, both series of fricatives have been retained (Venda has /ɸ/, /ɓ/ and /ɸ/, /w/ Doke (1954); see the discussion of Venda above).

The identity of the newly arisen labiodentals and the Proto-Bantu bilabials must have been kept apart until that change, because there was never a merger of the bilabials and the labiodentals (except, of course, for the cases in which obstruents turned into labiodentals before tense /u/), and no labiodentals ever shared the fate of the bilabials. (Also, the fact that anteriority was an important component of the newly created fricatives, can be seen from the fact that in some languages (e.g., Herero), /ɸ/ has progressed all the way to /s/ (Meinhof p. 27).)

Since the process of bilabial dissimilation in Southern Bantu is older than the phonetic change which created labiodentals (it is found in Tswana in the form virtually identical to that of Zulu, and somewhat modified in Pedi), it follows that there must have been a period in the history of Zulu, when this process had to distinguish between bilabials and labiodentals solely in terms of the presence vs. absence of the Labial Site. Since the mode of application of the process has not changed (cf. the comparative evidence from Tswana above), judging from the fact that it does not affect the labiodentals, one can conclude that underlyingly, labiodentals are not represented in Zulu with the Labial Site.

3.1.2.6 The point that Zulu labiodentals are not represented underlyingly as Labial (= with Labial Site) receives additional support from the fact that // patterns together with the alveolar fricatives of Zulu (s, z, ʃ, ʒ) in that it fails to undergo palatalization in the diminutive. The diminutive paradigm is illustrated below:

- (21)(a) u:p'hé:p'hé + ané --> ù:p'héšé:né 'fether'
 u:ú:bu + ané --> ù:ú:šé:né 'meal-water'
 ɪŋk'é:θɪ + ané --> ɪŋk'éšé:na/ɪŋk'éšé:né 'ox'
 ɪntsú:mp'hé + ané --> ɪntsúnp'hé:né 'wart'
- (b) ú:t'hɪ + ané --> u:t'hé:ne/ɪu:šé:neɪ 'stick'
 ùmgó:dl + ané --> ùmgóšé:ne/ùmgóšé:né 'mine'
- (c) ukú:ʒə + ané --> ũkuʒé:ne 'food'
 ɪmbú:zi + ané --> ɪmbuʒə:ne 'goat'
- (d) ɪsf:ɔ + ané --> ɪsfé:ne/ɪsfé:ne 'disease'
 ɪfu + ané --> ɪfé:ne/ɪfwé:ne 'cloud'

In the model of feature representation I am proposing, s, z, ʃ, ʒ, involve Tongue Blade constriction at an Anterior Site (recall that Anterior Site covers dental and alveolar points of articulation): a true labiodental, on the other hand, is characterized as involving a Lower Lip constriction at the Anterior Site. Therefore, the feature which groups these sounds into a natural class in this system, is the Anterior Site. The fact that these two groups of sounds pattern together in Zulu, provides additional evidence⁴ that Zulu labiodentals are represented underlyingly as anterior sounds.

With the discussion of Zulu, I conclude the section devoted to the feature Labial Site. I have considered the phenomena which appear to have all the characteristics of dissimilatory processes, and which affect only sequences of bilabial consonants and round vocoids, when such sequences arise as a result of derivation.

⁴ Of course, I concede that this type of evidence, since it expresses the feature of the process to take place, is not as strong as positive evidence.

Because labiodental consonants have at all times remained unaffected, patterning with non-labials, I have proposed that the conditions on representations responsible for these processes be stated in terms of an articulatory property which makes bilabial consonants and round vocoids different from labiodentals. The only such property, short of creating ghost features, is the constriction location: labial in bilabials and round vocoids, and dental (=Anterior) in labiodentals.

3.2 Anterior Site

I now turn to evidence for the existence of a feature Anterior. In the model I am proposing, this feature is defined differently from that of SPE or Sagey (1986). Recall that in SPE, this feature divided all consonants into [+/-anterior] classes, such that the segments articulated forward of the palato-alveolar region were [+anterior], and all others were [-anterior]; in Sage, (1986), this feature is distinctive only for the coronal sounds, and dominated by the coronal node; [+anterior] are the sounds with a constriction forward of the palato-alveolar region; [-anterior] are the remaining coronals. I use the label "Anterior" for a privative feature which characterizes the sounds with a constriction located in the dental or alveolar region. The class of sounds characterized by this feature includes: f, v, t, d, ʃ, ʒ, s, z, ʂ, ʐ, θ, ð, ts, dz, n, ɲ, etc., and complex segments involving these articulations. I assume that in addition to the above consonants, the class of Anterior segments may include vowels /i/ and /e/, in languages in which these vowels are articulated with a constriction in the dental/alveolar region. The arguments for the anteriority of such vowels are presented in chapter 5.

A controversial aspect of the list of sounds which I propose to characterize as Anterior, is that it includes the labiodentals with dentals and alveolars in a natural class. As far as I know, no system of feature classification has ever allowed these segments to form a natural class to the exclusion of all other segments. Yet /f/, /s/, /v/, /n/, etc., share an articulatory property -- they are all produced with a constriction in the dental/alveolar region of the mouth.

Current phonological theories do not question the fact that sounds articulated in that region form a natural class, as long as they share the coronal articulator; these theories do recognize the need for the feature ANTERIOR which maps onto the dental/alveolar region in the mouth. What they do not recognize is a possibility that non-coronal sounds may also be articulated in that region, and that this aspect of their pronunciation can be phonologically relevant, and can manifest itself in the same way that it does in the coronal sounds.

In this section, I present an argument from Standard Thai for the feature ANTERIOR which groups all segments with the constriction in the dental/alveolar region into a natural class.

3.2.1 Velarization of Anterior Consonants in Standard Thai (Siamese)

An interesting phenomenon of consonant-vowel interaction is reported by Harris (1972) in his phonetic description of Siamese consonants. According to that description, certain consonants of Siamese become velarized before "close front vowels". The consonants affected by this process are /i, s, ʋ/, out of the following segment inventory (Ruhlen (1975)): consonants: p^h, p, b, f, m, t^h, t, d, s, n, l, r, ʈ^h, ʈ, k^h, k, g, ŋ, ʔ, h; vowels: i, ɪ, u, e, a, o, ε, ɔ, a, plus the same series with length). The data that illustrate this phenomenon (from Harris (1972)) are shown in (22) below:

(22)(a)	tʰi:	'to hit'	(b)	te:	'eye'
	sʰi:	'four'		suaɪ	'pretty'
	rʰi:	'a boil'		te:	'a sky'

Other consonants in the language are not velarized before front vowels:

(23)	ke:	'to be twisted'
	di:	'good'

Velarization process described by Harris is a low level phenomenon: first it seems to be exceptionless, second, it is not a

neutralizing process: velarized segments are positional variants of the basic phonemes. Therefore, it cannot be disposed of as if it were an obscure morphophonemic alternation that has lost its phonological conditioning.

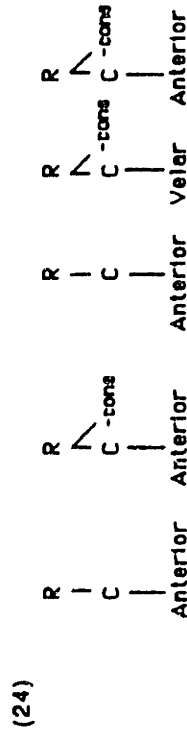
This process can be captured in terms of a natural class phenomenon only in a model of feature representation which allows classifying together sounds on the basis of their constriction location: sounds like /i, s, ʋ/ form a natural class only in terms of the feature ANTERIOR Site (I disregard the fact that these sounds share specifications for voicing and sonorancy, as these are clearly not the only features which pick them out of the segment inventory of Siamese).

At this point, it is not obvious what mechanism is responsible for the velarization phenomenon, why ANTERIOR segments should acquire a secondary velar articulation when followed by a front vowel. Ordinarily, palatalization phenomena are expected in such an environment. An analysis of this phenomenon depends on certain claims about vowel representation that I have not motivated yet. In chapter 5, I propose a treatment of vowels which relies on the claim that similar vowels of different languages may have different underlying representations, and that this factor is responsible for the differences in their phonological patterning. For example, I suggest that the vowel transcribed as /i/ may have a constriction

* Henderson (1982), while not suggesting that the velarization phenomenon is morphologically circumscribed, does wave away the fact that /i/ patterns together with anterior consonants, by undermining the phonemic status of /i/ as /i/: she suggests that velarized /i/ is really an underlying labialized aspirated velar that may surface with velarization as a reflex of its underlying shape. But this could not be correct: Harris does report the velarized /i/, as well as ordinary /i/ as variants of /khw/ in the speech of some Siamese, but he emphasizes that both such pronunciations are considered "low class" among the educated Siamese speakers, who do not merge /khw/ with /i/ in any position: velarized /i/ before close front vowels, on the other hand, is considered a standard (Harris (1972), p. 11 and 17). What this shows is that true /i/ must be velarized in the standard speech, and that merging of /khw/ with /i/ is viewed to be in poor taste. Finally, suggesting that Siamese does not have /i/ is completely unjustified on historical grounds. Comparative evidence (Li (1977)) suggests that Proto-Thai did have /i/.

location at either the Palatal or Anterior Site, and I show that such two different /ʉ/ map onto sounds with the predictable acoustic differences.

In chapter 5, I present arguments, based on the acoustic measurements, that /ʉ/ in Thai should be classified as an Anterior segment. Assuming this treatment of /ʉ/ now, it is possible to analyze the velarization phenomenon in Thai as a dissimilation process triggered by the OCP. Given the characterization of the velarized consonants as pronounced with a velar, /w/-like on-glide to the vowel (Henderson (1983)), I assume that the velarization process consists in the insertion of a glide which separates an Anterior consonant from an Anterior vowel*, and I propose to represent it as follows:



This concludes the discussion of velarization in Thai. This phenomenon is the only example I know of in which /ʉ/ patterns together with the Anterior /s/, /ʉ/, etc. It is not inconceivable that phonologies of languages contain more examples of such patterning, and that such examples may go unnoticed or be dismissed as "oddities". However, given the amount of descriptive knowledge that has accumulated in phonology in the recent years, it is not likely that such phenomena are extremely common. But if so, there should be systematic explanation as to why this should be the case. In the next section, consider such an explanation.

* Consonants cluster are allowed in Thai; since there are no reports of velarization affecting such clusters if they consist of Anterior consonants, I assume that only l-consonant segments may appear in the right-hand environment of the rule.

3.2.2 Cases in Which Labiodentals are excluded from the Phenomena affecting Dental/Alveolar Consonants

The phenomena which single out the so called anterior coronals (t, s, ts, etc) are generally much more common than the phenomena in which the dental/alveolar and the labiodental consonants pattern together. Some examples include a condition on representation in Basque (Hualde (1988)), which only allows anterior coronals in the coda (with palatal coronals and labiodentals in the inventory of segments), cooccurrence restrictions in Chinese (reference!) which disallow anterior coronals before front vowels in the same syllable, (with labiodentals in the segment inventory), apparent transparency of the anterior coronals only to the spread of features to the epenthetic vowel in Fula (Paradis and Prunet (1988)) (with labiodental /ʉ/ in the inventory), etc. etc.

The phenomena which affect dentals/alveolars, but do not include labiodentals can be handled within the constriction model, given the fact that this model can designate a natural class of anterior coronals (as an intersection of the class Anterior and the class Tongue Blade). However, it seems to me that such a treatment would miss a broader generalization that appears to be at work.

A possible reason for infrequent patterning of labiodentals and dental/alveolars has been hinted at in the context of a discussion of the articulator Lower Lip (section 2.1). There, I have suggested that in a language with no bilabial fricatives, and no phonological evidence for the "anteriority" of the labiodentals, the latter are to be treated as underlyingly represented with the Labial Site. I now discuss various aspects of this proposal in greater detail, and produce relevant arguments.

Given such a proposal, the task for a language learner is the following: unless there is evidence to the contrary, labiodental fricatives are mapped onto Labial underlying representations. This is not a controversial point, as phonologies of languages are filled with examples of sounds which do not pattern phonologically with the

classes of segments with which they classify on the basis of their surface acoustic and articulatory properties'. A well known example of this phenomenon is the case of the velarized lateral in Polish.

Polish displays on surface a sound that is in no way different from a round glide /w/. However, this sound, orthographically represented in Polish as /ł/, patterns with liquids, not with vocoids: before a front vowel, it becomes palatalized, and surfaces as /l/, e.g., *kowół* 'circle'; in extrasyllabic positions, it does not surface as /w/ as it ought to, given our current knowledge of vowel/glide alternations (cf. Levin (1985), Guerssel (1985)), but triggers epenthesis instead (Gorecka (1988)): *poswa/posEw* (E indicates the epenthetic vowel here).

This sound is still pronounced as /ł/ in the eastern dialects of Polish, just like /ł/ in Russian. Also, the stage pronunciation requires /ł/. These facts suggest that the surface shift from /ł/ to /w/ has taken place recently.

The event which might have led to /ł/ becoming phonetically /w/ in Polish, has most likely been the shift of the underlying /w/ to /v/ (the phenomenon which I am going to discuss in a moment on the basis of the Russian material), which emptied the acoustic and articulatory space of the round glide. The shift of /ł/ to /w/ is easy to understand -- both sounds are velars.

Other examples of camouflaged segments include the palatalized dental in Polish, which is represented as a distributed palatal alfricate (č/dž) in surface representation (a dental turns into č/dž when followed by /i/ or /e/, e.g., *koč/koće* 'cat', also, *č/dž* depalatalize to /d/ when a consonant-initial suffix follows: *kość*

* It is necessary to point out here that there is only partial resemblance between the cases of 'sound camouflage' that I am discussing below, and the case I want to make for the treatment of labiodental fricatives. In the former, we see clear phonological patterning which justifies positing an underlying segment different from its surface counterpart. In the latter, I propose to consider /f/ to be underlyingly represented as /ɸ/ when no evidence is available. Essentially, I assume a universal mechanism which specifies the site in the labial fricative as Labial, when no information is available.

'bone', but *kość* + k + a --> *kośka* 'little bone'); a voiced velar stop in Standard Arabic, which is represented on surface as /ʒ/: /ʒ/ fails to pattern with other coronals in the assimilation of the definite article /l/ (discussed in section 2.2.3 above), e.g., /l/ + *šams* --> *ššams* 'the sun', but /l/ + *gamaal* --> *lšamaal* 'the camel' (Brame (1970), cited in McCarthy (1989)), etc.

There exist well motivated cases of camouflaged bilabials. The best known example is that of a round glide in Contemporary Standard Russian, which surfaces as /v/. The phonemic status of Russian /v/ has been discussed on numerous occasions (e.g., Andersen (1969), Coats and Harshenin (1971), Halle and Vergnaud (1980), Hayes (1984), and others), because of its peculiar behavior w.r.t. voicing assimilation: /v/ patterns with sonorants, in that it is transparent to the spread of (de)voicing, while never acting as a trigger, e.g., /ot vdovw/ [dvd] from the widow', /bez vpuska/ [slp] without admission', but /s vami/ [sv] 'with you'. There is a fair amount of agreement that underlyingly, /v/ must be represented as a round glide: the most important factor is the phonological patterning with sonorants, but other factors matter as well: first, there is no surface round glide in the language, and so /v/ appears to fill the gap; second, in the speech of many speakers, there is free variation between /v/ and /w/, which suggests that the shift from the sonorant to the obstruent is not fully completed.

The relevance of the Russian data for the point I am pursuing here, is obvious: the rule that strengthens a bilabial sonorant to an obstruent produces a labiodental, not a bilabial segment. This suggests that the status of bilabial fricatives in surface representation is somehow more marked than the status of labiodental fricatives. A point of departure for an explanation as to why this should be the case, might be the fact that labiodentals have greater acoustic energy than /ɸ/, /β/. It has been observed

* The difference in the intensity has once served as the basis for distinguishing between labiodentals and bilabials in terms of a feature [strident], where labiodentals have been classified as [-strident], along with the sounds like *z*.

(Stevens (1980), Nartey (1979)) that generally, languages prefer high intensity over low intensity fricatives. Nartey (1979) suggests another reason for the relative markedness of /ʃ/, namely, that the structure of the mandibles might actually make the articulation of // easier than the articulation of /ʃ/. I would hesitate to adopt this idea, because it is not obvious to me how bilabial stops are to be exempted from its broad consequences.

If only perceptual considerations are the reason for low surface occurrence of /ʃ/ (In Nartey's data base of 317 languages, 132 have //, but only 20 have /ʃ/, and only 31 have /βʃ/), then it is not unreasonable to assume that the choice between bilabial and labiodental articulation is a matter of a very late rule in the derivation of phonetic representations.

There are (at least) two advantages of assuming that most labiodentals are underlyingly bilabial: first, the inventories of languages more often than not display a symmetry in the way the segments are distributed within the articulatory space. Consider, for example, the obstruent inventory of Polish (disregarding the palatalized articulations):

(25)	Labial	Anterior	Palatal	Velar
	p	t ts	č	k
	b	d dz	ž	g
		f s	š	x
		v z	ž	

If labiodentals aligned with /p/, /b/ under Labial Site, the obstruent inventory of Polish would be almost perfectly symmetrical, having two fricatives at each constriction site (minus the absence of

etc. (Chomsky and Halle (1968)) (for a discussion of this extension of [strident], see chapter 6).

^a I am grateful to Ken Stevens for discussing this topic with me.

^b Incidentally, the occurrence of other low intensity fricatives -- interdental -- is in the same region: 17 languages have ʂ, and 20 languages have ʐ.

voiced velar fricative which merged with /g/. Now compare the obstruent inventory of Polish to that of Basque (Hualde (1988)):

(26)	Labial	Anterior	Palatal	Velar
	p	t ts	c č	k
	b	d	ʃ ž	g
		f s	š	x

The asymmetry of classifying // apart from bilabial consonants is even more conspicuous here: Basque has only one fricative (voiceless) for each constriction site, excluding the bilabial and the palatal fricatives. The absence of the palatal fricative is just a gap in the inventory; it is not the case that /ç/ groups asymmetrically with some other class of sounds. However, the missing fricative under the Labial Site is quite obviously //l. This observation squares neatly with the fact reported at the beginning of this section, that labiodental is not allowed in the coda in Basque, even though the other Anterior (and only Anterior) segments are.

D. Steriade (p. c.) has pointed out to me another argument for treating // in languages like Polish or Basque as underlyingly represented with the Labial Site: a look at the inventories of these languages shows very clearly that they are arranged in terms of classes defined in terms of Site features, not the Articulator features. This makes the asymmetrical behavior of // in these languages even more conspicuous.

The second advantage of representing // as underlyingly bilabial in languages which show no evidence for its anteriority, is that it explains infrequent patterning of labiodentals with other Anterior segments: if // is underlyingly Labial/Lower Lip, then it should come as no surprise that it fails to pattern phonologically with the Anterior consonants.

3.3 Palatal Site

I assume that all sounds articulated with a constriction along the hard palate are characterized with the feature Palatal. This includes sounds which have been variously described in the literature as pre-palatal, alveo-palatal, palato-alveolar, palatal, dorso-palatal, etc. I assume that phonemic distinctions among the Palatal sounds are carried out, first, by the articulators which execute the constrictions (Tongue Blade and Tongue Body), and then, by the features associated with the articulators (in the case of coronals -- [+/-distributed], [+/-lateral]; as far as the dorsal palatals are concerned, I have not seen a language that would contrast these sounds along more dimensions than [+/-voice], therefore, I believe that the issue whether the features [back] and [high] are ever used phonemically among them, is moot^{*}.

The following sounds are included among Palatals: č, ʃ, ʒ, ʧ, ʤ (palatal coronals), c, ɟ (palatal stops), ç, ʝ (palatal fricatives). While the subject of the constriction location of front vowels will be taken up properly in the chapter on representations, for the purposes of this section, I am going to assume some of the claims that are still to be argued, in particular, the claim that vowels /i, e, ü, ö/ belong among palatal sounds. Of course, to some extent, the evidence presented below supports such a view, as it shows these vowels interacting with Palatal consonants in ways that can only be understood if the two classes of sounds share an articulatory feature.

The status of the feature Palatal within the articulator model (Sagey (1986)) parallels the status of the feature Anterior in that model: since Palatal is [-anterior], and the feature [anterior] is dominated by the Coronal Node, the only segments that can be

^{*} Note that /c/ (the palatal stop) and /k'/ (fronted velar), which are both dorsals, are distinguished not in terms of the Tongue Body features, but in terms of the Site: the former is represented with the Palatal Site, and the latter -- with the Velar Site. These representations are motivated in chapter 5.

characterized in terms of this feature, are coronals. The point of this section is to show that Palatal constriction location can be a phonological property of both coronal and dorsal sounds.

In order to argue for the feature Palatal as distinct from [-anterior] of the Sagey model, I will focus on the phenomena in which palatal coronals pattern with consonants whose palatal constriction is executed with Tongue Body: either dorsal palatals (e.g., Margi, Arumanian), or palatalized consonants (Russian (standard dialect), Bulgarian).

Among the phenomena which justify positing the feature Palatal Site, palatalization processes figure most prominently. Since in these processes a dorsal front vowel quite commonly induces a "coronalization" effect in a consonant, it is here more than anywhere else, that the need for positing the feature Palatal Site becomes strongly apparent. Because the treatment of palatalization which I propose cuts across a number of theoretical points in this thesis, I do not present it in this section, but discuss it separately in chapter 7.

3.3.1 Palatalization of Unstressed Vowels in Russian^{*}

In Russian (segment inventory (Jones and Ward (1969)): p, p', b, b', f, f', v, v', m, m', t, t', d, d', ts, s, s', z, z', n, n', ʧ, ʤ, ʃ, ʂ, ʂ', ʧ', ʤ', ʃ', ʂ', e, u, o, ə), the surface quality of unstressed vowels is conditioned by a number of factors: the underlying quality of the vowel, the position of the vowel w.r.t. the main stress, and the quality of the preceding consonant.

It is this last factor that is of theoretical interest to us: as I will show in a moment, all consonants of Russian that are classed as Palatal on the constriction model, pattern alike in the process which affects the quality of unstressed vowels in the language, regardless of what their specification for the Articulator feature might be.

^{*} Thanks to Michael Kenstowicz for directing my attention to this phenomenon.

In what follows, I outline the entire paradigm, and then focus on the cases in which the unstressed vowel assimilates to the quality of the preceding consonant. I show that in order to have a simple account of such assimilations, it is necessary to appeal to the concept of palatal constriction location (Palatal Site).

The following rules derive surface representations of unstressed vowels in Russian (based on Jones and Ward (1969)): /u/ and /w/ are lax:

$$(27) \quad i, u \rightarrow 1, 0 / \frac{\quad}{-31033}.$$

for example (stressed vowel is in bold type):

(28)	jəzdɪtʰ	/jəzdɪtʰ/	'to travel'
	prʰiʈɪnə	/prʰiʈɪnə/	'cause'
	tʰiskɪ	/tʰiskɪ/	'vice'
	orək	/orək/	'lesson'
	oʒɛ	/uʒɛ/	'already'
	znə o	/znə u/	'I know'

/e/ is raised and lax (presumably, by the same process that laxes high vowels):

(29) θ --> [+high] / _____
 -stress

This is illustrated below:

(30)	ɪ'ɪktrɪ'čɪstvə	/eɪ'ektɪrɪ'tʃestvə	'electricity'
	sɪ'mɪnə	/sɪ'mənə/	'seeds'
	pɪ'rɪ'mɪ'ɪʃ	/pɪ'rɪ'mɪ'eɪʃ/	'grind', imperf.

The quality of /a/ and /o/ depends on their position in the word relative to where the main stress is, and on the quality of the preceding consonant: in the pretonic position, these vowels surface as /ɪ/ when following a front glide, a coronal palatal (/č, ʃ, ž/), or a

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palatalized consonant (/ʲ, ʲ', ... ʲ). After all other consonants and word-initially /a/ and /o/ surface as /ʌ/. This is summarized in (31), and illustrated in (32) below:

$$(31) \quad a, 0 \rightarrow I / \{c, \$, z, v^!, \dots\} \text{ --- } C V + cross$$

otherwise:

a, c --> 1 / C V
+3/1989

(32)(a)	jɪʔk	/jɔʔk/	'tongue'
	ʧɪʔ	/ʧɔʔ/	'watch'
	pʰɪʔ	/pʰɔʔ/	'five', gen.
	jɪʔ	/jɔʔ/	'hedgehog'
	ʒʔ	/ʒɔʔ/	'wife'
	nʰɪʔ	/nʰɔʔ/	'was taking', fem.

(b)	samo	/sama/	'self', fem.
	gʔaʔo	/gʔoʔo/	'eyes'
	znʔoʔo	/znʔoʔo/	'know', fem.

to go	/ɪ'pɒx/	obvɛ
houses	/əwɒp/	əwɒp
bag	/əbɒg/	əbɒg

Before presenting the rest of the paradigm, I would like to comment on the presence of /ɪ/ (/ɛ/, if unstressed) in some of the examples above. The i/ɪ alternation in Russian is unrelated to the vocalic phenomena in pretonic syllables; it represents a more general process, whereby /ɪ/ is "backed" when following the so called "hard" consonants. The class of "hard" consonants includes all unpalatalized segments, as well as the [+continuant] coronal palatals /ʃ, ʒ/.

The 1/4 alternation is explained below.

I adopt the standard analysis of the /i/ alternation, which treats the "hard" consonants of Russian as velarized*, and considers the presence of /i/ after these consonants to be a result of a rule which spreads the backness of the velarized consonant onto the vowel /i/ (e.g., Jones and Ward (1969), Chomsky and Halle (1968)). This interpretation is well supported by the evidence of the X-ray tracings of the Russian sounds (e.g., Fant (1960), p. 170, 186), which reveal secondary velar constrictions in p, s, t, š, etc., rather similar to the constriction present in the articulation of the vowel /i/ (Fant (1960), p. 170).

I now return to the characterization of vocalic alternations in unstressed positions, and conclude the paradigm with the presentation of /a/ and /o/ in other than pretonic positions. Word-initially, /a/ and /o/ surface as /ʌ/; otherwise, they surface as /ə/. The statement of the rule, and the examples follow:

(33) a, o --> ʌ / ; otherwise: a, o --> ə

-stress

(34)(a) advakət /ədʌvəkət/ 'solicitor'
 ʌftʌmət /əftʌmət/ 'automaton'
 ʌdnəvə /ədnoɡə/ 'of one'

 ʌpʌzdət /ɒpɒzdət/ 'was late'

(b) təbur'etke /tebur'etke/ 'stool'
 pərxot /pərxot/ 'steamer'

 məʃʌko /məʃʌko/ 'milk'
 ɡarʌdə /ɡarʌdə/ 'towns'

* The presence of /ɛ/ (as well as /ɛ/) in that group is not very easy to explain: /ɛ/ is a palatal consonant, and this alone should suffice to block the velarization process, (e.g., /ɛ/ is not velarized). On the other hand, it is possible that velarization of /ɛ/ is a separate phenomenon, unrelated to the rule which affects non-palatal consonants. Unlike /ɛ/, /ɛ/ is an apical consonant; one could view velarization of /ɛ/ as an enhancement of its apical quality, but see Stevens and Keyser (1986) for a different view.

There are several plausible analyses of the above phenomena. For example, it is possible to treat the assimilation of a pretonic vowel as a process separate from vowel reduction: in such a case, the assimilation would involve spreading of the palatal constriction of a consonant onto an adjacent (pretonic) vowel, followed by the deletion of the original constriction(s) of the vowel. Alternatively, it could be assumed that Russian has a general rule of vowel reduction in unstressed positions, and that the assimilation of the pretonic vowel involves the spread of the Palatal Site of a consonant onto an empty position of the vowel. Ultimately, I adopt the second analysis (see below), as it allows for the simplest account of the phenomenon.

However, what needs to be stressed at this point, is that technical differences aside, all analyses of the assimilation phenomena must be able to characterize in terms of a natural class the set of segments which condition the assimilation. As I have shown, this set consists of all palatalized consonants of the language, the coronal palatals, and the front glide.

Konstowicz and Kisseberth (1979) propose an analysis of vowel assimilation in Russian based on the assumption made in SPE, that /ɛ/ and /ɛ/ are [-back, +high]. On this assumption, it is possible to characterize the set of segments which condition vowel assimilation in terms of a natural class, since both /i/ and the palatalized consonants of Russian can also be treated as [-back, +high].

There is a serious problem with the SPE treatment of /ɛ/, /ɛ/. However: there are no documented cases of /ɛ/ or /ɛ/ acting like [-back, +high] segments w.r.t. vowel harmony -- they do not block the height or the backness harmony. Consider, as an example, the backness harmony in Turkish: Turkish (segment inventory (Ruhlen (1975)): l, ü, t, u, e, ö, a, o; p, b, f, v, m, t, d, s, z, n, l, c, ç, ş, k, g, ʔ, h) has a harmony which assimilates in backness the suffixal vowels to the stem vowel. As shown below, this harmony is not

blocked by either /č/ or /ž/, regardless of what value of [back] spreads (data are taken from Halle and Clements (1984)):

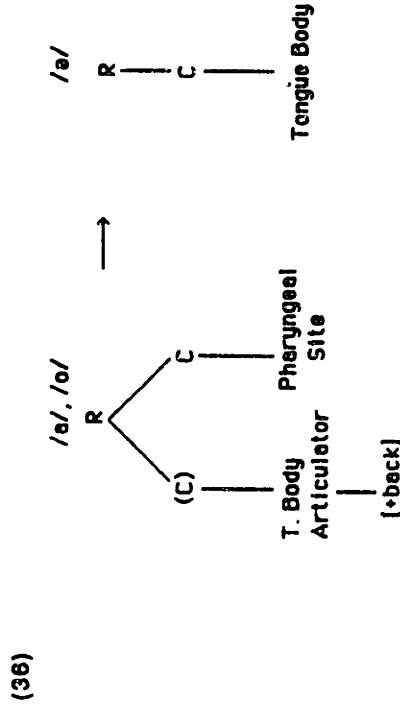
(35)	seč	seč4	seča	sečten	sečler	sečler4	'neir'
	güč	güčü	güče	güčten	güč1'er	güč1'eri	'power'
	genč	genč1	genče	genčten	genč1'er	genč11'eri	'young'

Also, /č/ and /ž/ do not spread the height feature individually (e.g., there are no cases of /o/ and /e/ raising to /u/ and /i/ after /č/, /ž/). These facts strongly suggest that coronal palatals are not represented in terms of the tongue body features. Therefore, there is no feature or features within the articulator theory of phonological representation (Sagey (1986)), that would characterize as a natural class the segments which condition vowel assimilation in Russian; under this theory, coronal palatals are [coronal], and /j/, as well as the segments involving secondary palatalization, (e.g., /tʃ/, /pʃ/, etc.) are [dorsal].

Yet it is beyond doubt that in purely phonetic terms, these segments do share an articulatory property: they all involve a constriction in the palatal region of the mouth. I have pointed out earlier that the model of feature representation of Sagey (1986) does recognize the need for a feature that represents the palatal constriction location, but limits its use to the coronals by making it a dependant of the Coronal Node. Since it is clearly not true that only coronal segments can have a palatal (= [-anterior]) constriction, by making this feature independent of the articulator(s), we allow for a system of representation more faithful to the phonetic reality, and more capable of capturing relevant phonological generalizations. In such a system, the set of segments which assimilate the reduced pretonic vowel to /i/ in Russian is characterized with one feature: palatal point of articulation.

Let us now proceed with an analysis of the assimilation phenomena, beginning with the processes affecting /a/ and /o/. I assume that vowels /a/ and /o/ in Russian undergo reduction in

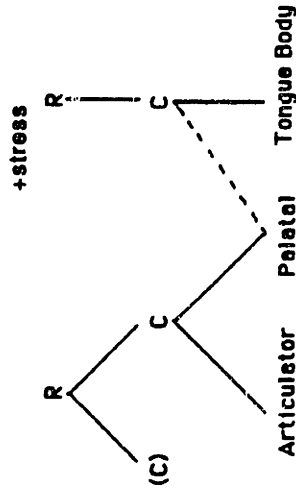
metrically weak, unstressed positions. The immediate output of this process is a so called "reduced" vowel -- a segment with no Site specification. (This treatment of the reduced vowels correlates with the articulatory and acoustic facts; according to Fant (1980), p. 210, an openly articulated sound, may have the formant pattern of a neutral vowel /ə/) regardless of where the tongue constriction is located; therefore, the reduced vowel is a segment whose constriction location is variable, or -- in phonological terms -- unspecified. For more discussion see chapter 5). Let us represent this process as follows:



If the vowel /a/ remains in the metrically weak position throughout the derivation, it surfaces as /ə/. According to Jones and Ward (1969) p. 54, "in the immediately pretonic position, which is the second most heavily stressed syllable in Russian words, [...] the Russian sound /a/ does not occur". Instead, either vowel /i/ (/ɪ/), or /ʌ/ occurs in this position.

Vowel /i/ surfaces in the pretonic syllable, whenever preceded by a palatal coronal, palatalized consonant or the front glide. I propose to treat this process as spreading of the Palatal Site of a consonant onto the Constriction Node of a stressed vowel, and I represent it as follows:

(37)



Since the processes which manipulate the Articulator and the Site nodes may apply in a feature filling fashion only (see 1.3, and chapter 7), the rule in (37) will not affect stressed vowels which are fully specified.

When following a non-palatal consonant, the pretonic vowel surfaces as /ʌ/, characterized by Jones and Ward (1989) as a back vowel, close to /ɔ/, but with the lip rounding removed (p. 50). On the basis of this description, it is possible to hypothesize that /ʌ/ is a vowel with a velar and pharyngeal constrictions, just like /ɔ/, but with no labial constriction. Since the same vowel is substituted for /a/ and /o/ in the word-initial position, I hesitate to derive its quality from the influence of the velarized consonant. Instead, I assume that this quality is assigned to stressed reduced vowels by a default rule. However, such an influence cannot be ruled out, as both /ʌ/ and non-palatal consonants contain the velar component.

The processes affecting /i/, /u/, and /e/ in unstressed syllables must necessarily be treated separately. Since they are of little importance to the issues at hand, I will consider them very briefly: the change of /e/ to /i/ is best treated as a reduction of a complex segment -- more examples of similar phenomena will be discussed in chapter 5. Laxing of /i/ and /u/, on the other hand, is a manifestation of a more general process: only vowels with main stress may surface as [+tense] in Russian, vowels in all other positions are always lax. This can be expressed with the following

rule (which must be applied prior to the assignment of the pretonic stress):

(38) V --> [-tense] / _____ -stress

This concludes the discussion of vocalic alternations in unstressed syllables in Russian. The proposed analysis presents a view according to which vowel reduction affects all cases of unstressed /a/ and /o/. This process creates representations which are incompatible with the secondary stress assigned later to pretonic syllables. The need for fully specified vowels in these positions drives the assimilation process responsible for the "palatalization" of the pretonic vowel.

The advantage of analyzing this assimilation as mediated by the process that creates a reduced vowel (represented here as a segment with no Site specification) is that only those segments of Russian whose constriction location is compatible with the Tongue Body articulator (Palatal or Velar) will be allowed to contribute to the quality of the pretonic vowel. This analysis explains, for example, why this vowel never acquires the labial component from the preceding /p/, /b/, /m/, etc.

Finally, by appealing to the phonological concept of Site, the proposed analysis represents in a simplest possible way the fact that segments such as /č/ /ʃ/ and /j/ pattern together in a phonological process, despite the fact that they do not form a natural class w.r.t. the articulator active in the constriction.

3.3.2 a/e Alternation in Bulgarian

Scatton (1984) reports the following alternation in Bulgarian (segment inventory (Scatton (1984))): p, p', b, b', f, f', v, v', m, m', t, t', d, d', ts, ts', s, s', z, z', n, n', l, l', r, r', č, dž, š, ž, k, g, x, t, e, u,

o, e): stressed' /a/ preceded by a palatalized consonant alternates with /e/, when it is followed directly, or across an intervening consonant, by a coronal palatal, a palatalized consonant, front glide, or a front vowel (in Bulgarian -- only /i/ or /e/). Concomitant with the change of /a/ to /e/ is a depalatalization of the consonant that precedes the alternating vowel. This paradigm is illustrated below (stressed vowels are shown in bold type):

(39)(a)	gr'ex	'sin'	gr'ska	'error'
	pr'ek	'straight'	pr'ečt	'I hinder'
	b'el	'white'	be'l'u	'I bleach'
	m'erka	'measure'	me'r'it	'I measure'
	p'el	'he sang'	pe'jt	'I sang'
	bi'ex	'I bleated'	ble'je	'I bleat'
	v'a	'it blew'	vee	'it blows'
(b)	sl'ep	'blind'	slepčo	'blindmen'
	x'leb	'bread'	xlebče	'little bread'
	m'esto	'place'	mešt'it	'I move'
	v'ars	'faith'	verl	'faiths'
	l'av	'left'	levl	'left, pl.'

An analysis of the above facts can be offered only to the extent to which we understand the phonological processes which require an identical, or at least a similar environment on both sides of the target, a "feature bridge" of sorts. Such phenomena are not uncommon (e.g., Wolesian (Howard (1973)) has a rule which raises /a/ to /e/ between two high vowels; Kihunde (Goldsmith (1984)) has a rule which raises a low tone flanked by two high tones, etc.), but so far, they are poorly understood.

For this reason, the interpretation of a/e alternation proposed here is rather tentative. I assume that the mechanism responsible

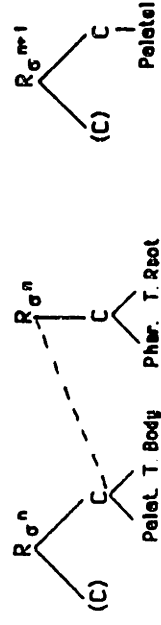
* Unstressed /a/ surfaces as /e/ whenever preceded by a palatalized consonant; there is no requirement that there be a palatal segment on the right.

for the alternation is a palatalization process in the sense defined in Chapter 7: the process which spreads palatal constriction. When the palatal constriction spreads onto the Root Node of a pharyngeal vowel /a/, the result is a complex segment with both pharyngeal and palatal articulations: /e/.

Most likely, the segment to which the vowel assimilates, is the consonant on the left. This hypothesis is based on the fact that when a palatal coronal appears in that position, the assimilation fails to take place (cf. zvučel/zvučell 'sounded'). The absence of palatalization in this case can be explained if we assume that only the segment on the left can spread the palatal constriction, and that only the Palatal/Tongue Body constriction may spread onto a vowel.

Under these assumptions, the palatalization process may be represented as follows:

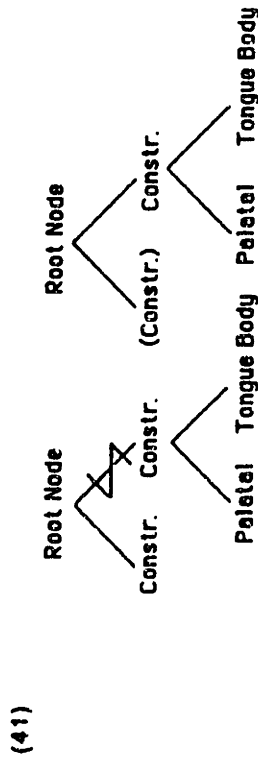
(40)



[Subscripts on the Root Nodes indicate adjacency conditions: the right-hand palatal segment must appear in a syllable adjacent to the syllable that contains the target.]

A detail that remains to be explained is the alternation which involves the consonant on the left: in the forms with /a/, it is palatalized; in the forms with /e/, it appears to have lost palatalization. Apparently, this phenomenon is not restricted to a/e alternation. It is true without exception in Bulgarian, that palatalized consonants may not be followed by front vowels; when such a sequence arises as a result of affixation, the consonant is depalatalized, e.g., kon' + o --> kon'o 'horse, voc.', but kon' + e --> kone 'horses'. The data in (39) indicate that depalatalization also takes place when such a sequence arises as a result of a

phonological rule. For the purposes of this presentation let us assume that depalatalization applies to any sequence of segments which bear palatal specification, and that it deletes the palatal constriction of the first segment*, as shown below:



Let us conclude the discussion of a/e alternation in Bulgarian, by emphasizing the relevance of this phenomenon to the claim that there exists a phonological feature Palatal Site, and that this feature maps onto palatal constriction location. Palatalization of a stressed /a/ takes place only when the vowel follows a palatalized consonant, and precedes a syllable containing either a palatal vowel (/i/ or /e/), a palatal coronal (/t/ or /ʃ/), a palatal glide (/j/), or a palatalized consonant (/pʲ/, /tʲ/, etc.). Since the only articulatory property that separates /i, e, ɛ, ɟ, ʃ, j, pʲ, tʲ, etc./ from all other segments of Bulgarian is the palatal constriction location, we can conclude that this property forms the basis of the phonological feature which plays a role in the palatalization phenomenon, the feature Palatal Site.

3.3.3. The a/e and o/e Alternation in (Old) Polish

* It is possible that depalatalization process serves two different purposes, on one hand, it satisfies the OCP requirement that there will not be two adjacent palatal constrictions, and on the other hand, it satisfies the constraint against doubly linked matrices (the fact that geminate consonants are not well tolerated in Bulgarian (cf. Scatton (1984)) supports this point). I do not discuss these possibilities in detail, because the problem of depalatalization is only remotely related to the topic at hand.

The phenomenon that I am about to report has lost phonological generality in the modern day language, but at some point, must have been a part of Polish phonology. (Segment inventory of Polish (Schenker (1973): and my own corrections with regard to the apical consonants): p, pʲ, b, bʲ, t, tʲ, v, vʲ, m, mʲ, l, ɫ, ts, s, z, n, ɲ, ʃ, ʒ, ʂ, ʐ, ʑ, dz, k, g, x, ɣ, e, u, o, ə). The facts are, to some extent, the mirror image of the situation found in Bulgarian: /o/ and /a/ become /e/ when preceded by either a glide /j/, a palatal coronal /ʃ/ or /tʃ/, or a palatalized consonant (/pʲ, tʲ, etc.), and followed by a palatalized segment. The following are some of the examples that have retained the alternation:

(42)(a)	Jedō	'they go'	Jedže (dž=ɟ)	'goes'
	kv'at	'flower'	kv'eč'istʲ	'flowery'
	černʲ	'black'	černʲ	'blackness'
(b)	p'osenko	'song, dlm.'	p'eš'ŋ	'song'
	pščola	'bee'	pščel'ŋ	'bee, adj.'

The analysis of the above data follows the same path as the analysis proposed for the a/e alternation in Bulgarian, except that in Polish, the palatal constriction must spread from the segment on the right; when this segment is a coronal palatal, such as /tʃ/, the rule does not apply, e.g. kšak/kšoček/kšočesty 'bush/little bush/bushy'. Also, in Polish, /o/, in addition to /a/, participates in the alternation. The o --> e change can be explained as follows: when the palatal constriction spreads onto /o/, represented here as a complex segment with a velar and pharyngeal constrictions* (see chapter 5), the velar constriction is deleted as incompatible with the palatal constriction (vowel with both palatal and velar constriction would necessarily have to have a single articulator (Tongue Body) involved in two different constrictions; it has been suggested earlier (see the

* In Polish, this segment surfaces as 'č', a palatal affricate; see the comment in Section 3.2.3.

* I consider rounding to be redundantly specified in vowels with a velar constriction.

introduction, also Sagey (1986)) that complex segments in which any feature specification is repeated are disallowed).

The conclusion that follows from examining the Polish data is the same as the conclusion that we have reached on the basis of the Bulgarian example: in order to be able to capture the essence of a phenomenon in which a front glide, a palatalized segment and a palatal coronal pattern alike, a phonological theory must recognize the feature Palatal Site (or its equivalent), independent of the features which specify active articulators.

3.3.4 e/o Alternation in Arumanian

Arumanian (segment inventory (Golab (1984)): p, b, f, v, t, d, s, z, ts, dz, č, dž, š, ž, k, k', g, g', x, x', y, (y'), m, n, n', l, l', l, u, e, o, œ/œ, ə, œə/ɔ, ə) is a Romanian dialect, now thoroughly mixed with Macedonian (sometimes referred to as Macedo-Romanian for that reason), spoken in Macedonia. The phonology and morphology of this language is described in some detail by Golab (1984), on whose description these comments are based.

/ə/ is an underlying vowel of Arumanian, and it can appear freely in almost any environment, except when preceded by a coronal palatal or a palatalized segment. In the latter cases, morphological */ə/* surfaces as */e/*. This is shown in the examples below, where the third person Aorist ending alternates between */-ə/* after non-palatal endings and */-e/* after stems that end in a palatal:

(43)(a)

purɬ	+	ə	→	purɬə	'carried'
lukr	+	ə	→	lukrə	'worked'

(b)

bəʃ	+	ə	→	bəʃə	'kissed'
təɭ	+	ə	→	təɭə	'cut'

The facts of Arumanian are quite similar to the $\emptyset/i$ alternation facts in Russian, discussed in section 3.3.1. In both languages the vowel that assimilates to a palatal segment is $/e/$, and in both languages the trigger can be either a dorsal or a coronal palatal. Drawing on

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these similarities, I propose to analyze the Arumanian data much in the same way that I have analyzed the Russian case.

I assume that the assimilatory feature in Arumanian is the Palatal Site, which spreads from a palatalized consonant or a coronal palatal onto the Constriction Node of a reduced vowel. Here again, what makes such a rule possible, is the fact that the Site specification is absent from the representation of the reduced vowel (see 1.3, and chapter 7). Therefore, the assimilation is a feature-filling process.

Despite many similarities, there are also differences between the Arumanian and the Russian case, the most important difference being in the quality of the assimilated vowel -- /i/ in Russian and /e/ in Arumanian. A plausible explanation for this difference might be that at the point when the rule applies in Russian, the height of the reduced vowel (predictably [-high], see the discussion in chapter 5) is not specified. In such a case, following the assimilation, the feature composition of the newly assimilated vowel (Palatal/Dorsal) will yield a redundant [+high] specification on the Tongue Body Node. Suppose now that the reduced vowel in Arumanian is specified as [-high] at the time when the assimilation takes place: in such a case, after the spread of the Palatal Site, one of the following two can happen: either the [+high] specification becomes deleted, or else, the pharyngeal constriction is added to the Root Node of the vowel (on the assumption that /e/ is always a complex segment). The latter appears to be the order of derivation in Arumanian.

3.3.5.5 Palatalization of /ə/ in Margi

[illegible]

palatal dorsals (c, ʃ, ʧ, ʤ), front glide (j), and palatal coronals (č, ʃ, ž, ʒ), word-final (but not phrase-final) /ə/ turns into /ʌ/. In the absolute phrase-final position, /ə/ turns into a vowel which Hoffman describes as "a centralized close back vowel without lip rounding" (p. 21), and transcribes as /ʉ/. This change affects only /ə/, and it occurs regardless of the quality of the preceding consonant. It is because of this additional alternation, that we can distinguish an underlying /ʌ/ and /ʉ/ derived from /ə/ after palatal consonants: the underlying /ʌ/ is not affected in the phrase-final position. The following examples illustrate the paradigm:

(44)(a)

/ə/ in word-final position:

/ə/ in phrase-final position:

sǎ	sù	'thing'
mdá	mdù	'person'
bǎǎ	bǎy	'chew'
dǎfǎ	dǎfǎy	
'mush'	yǎfǎy	
yǎfǎ		
'arrow'		

ʔ	ʕ	ˈspek
s	ʃ	ˈspɪn
ʒ	ʒ	ˈcləɪm frɪst

‘like’

(tư)	củ	'leaf'
(hết)	hấc củ	'core for'
(đ)	náy	'burn'

(b)

/i/ in word-final position:

/i/ in phrase-final position:

Water	ml	ml
water	ml	ml

— 60 —

315
316

3113 3114

.true.
.false.

The Margi facts greatly resemble *e/i* alternation facts in Russian. Therefore, we can assume that the analysis¹² which we have proposed for Russian extends to Margi straightforwardly: the change of /*e*/ to /*i*/ after a palatal segment involves the spreading of the Palatal Site of a consonant onto the Constriction Node of the reduced vowel; again, what makes such a rule possible is the fact that the reduced vowel is represented with no Site specification.

The fact that the assimilated vowel surfaces as // suggests that in Margi, just like in Russian, the rule spreading Palatal Site applies prior to the rule which provides /ə/ with the height specification. The segment which results from the assimilation is represented with a single Constriction Node: Palatal/Tongue Body; such matrices are redundantly specified as [+high].

It is not clear why /a/ becomes palatalized in the word-final position only. One possibility is that while not mentioned by Hoffman, this position is metrically strong in Margi. On the other hand, I have not found cases of /a/ following a palatal consonant in the word-internal position. Apparently, this question cannot be resolved until more is known about the language.

With the Margi case, I conclude the present section. Let us briefly summarize its main points: (1) We have seen a number of phenomena in which sounds produced with a constriction in the palatal region of the mouth pattern alike, despite the fact that they are not executed with the same articulator. These phenomena have been shown to constitute evidence for the feature whose phonetic base is the palatal region of constriction -- the feature Palatal Site. (2) These phenomena have been analyzed in the manner which not only captures the fact that segments with palatal constriction form

a natural class, but also explains the behavior of these segments in phonological processes.

3.4 Velar Site

The region of the mouth which forms the articulatory basis for the feature Velar Site is the soft palate. Since the only articulator that can form a constriction in this region is the tongue body, all velar sounds are necessarily dorsal. This makes the task of arguing for the phonological constituency of the Velar Site somewhat difficult: any process that affects a velar consonant (k, g, x, ɣ, ŋ) can be ambiguously interpreted as targeted at either the dorsal or the velar specification; many processes that affect velar vowels (/u/ and /o/) can be analyzed in terms of backness or labiality, usually without greatly compromising the phonological generalization.

In order to argue for the Velar Site, it is necessary to contrast the behavior of velar sounds with the behavior of other dorsals. In what follows, I present two such cases: the case in which velar consonants undergo dissimilation before velar consonants and vowels in Polish, and the case in which velar vowels turn into velar consonants in Kinyarwanda.

3.4.1 Velar Palatalization in Polish

There are several suffixes in Polish which trigger palatalization of stem-final consonants, but only if these consonants are velars. The suffixes are /-k/ (diminutive /agent/feminine), /-us/ (diminutive/agent), /-uŋ/ (diminutive). The following examples illustrate their phonological behavior:

(45)(a)	pij-ek	pij-eč-k-a	'drunkard'
	nog-a	nuž-k-a	'leg'
	ux-o	uš-k-o	'ear'
	kot	kot-k-a	'cat'
	mis-a	mis-k-a	'bow'

	žeb-a	žeb-k-a	'frog'
	rur-a	rur-k-a	'pipe'
	xtop	xtop-k-a	'peasant'
(b)	nog-a	nož-uš-a	'leg'
	vilk	vilič-uš	'wolf'
	tat-o	tat-uš	'dad'
	mam-a	mam-uš-a	'mom'
	rab-ov-a-č	rab-uš	'thief'
	syn	syn-uš	'son'
	tsur-a	tsur-uš	'daughter'
(c)	rěk-a	rěč-uŋ-a	'hand'
	nog-a	nož-uŋ-a	'leg'
	mam-a	mam-uŋ-a	'mom'
	tat-o	tat-uŋ-o	'dad'
	beb-a	beb-uŋ-a	'grandma'
	tsur-a	tsur-uŋ-a	'daughter'

In order to interpret the above data correctly, it is necessary to compare the behavior of /-k/, /-us/, /-uŋ/ with the phonological patterning of other suffixes in the language. Polish suffixes can be divided into two main categories, depending on whether they do or do not trigger palatalization. I shall now characterize these categories briefly.

Palatalizing suffixes turn stem-final labials and dental/alveolars into their palatalized counterparts, and velars into palatal coronals, e.g., /-isko/ (augmentative): xtop/xtop'isko 'guy', kot/kot'isko 'cat', pijek/pijəč'isko 'drunkard'. The palatalization process may be represented as the spread of the palatal constriction of a vowel onto the Root Node of the preceding consonant; when applying to the labials and dentals/alveolars, this process derives complex segments: palatalized labials, palatalized dentals, etc.

* Remember from the previous discussion (section 3.2.3) that /l', s', z'/ surface in Polish as /č, š, ž/ -- [-distributed] palatals.

Since these segments are present in the phonemic inventory of Polish, nothing can prevent them from surfacing when they are derived via a phonological process (see the discussion of palatalization in chapter 7). In the case of velars, it may be assumed that following the spread of palatal constriction, the velar constriction is deleted. The resulting palatal segment is realized as a coronal¹ (because there are no dorsal palatals in the language).

Palatalizing suffixes fall into two sub-categories: those with an overt palatal component, e.g., /-isko/ (augmentative), /-ina/ (nominalizing), /-ik/ (diminutive), /-el/ (nominalizing), and those that on surface appear to begin with non-palatal segments: /-ar'/(agent), e.g., mleko/mlečaś 'milkman', nuda/nudz'aś 'bore', baba/bab'aś 'womanizer'; /-ak/ (attributive), e.g., xudt/xudžak 'thin', strax/strašak 'fear', /-asv/ (adjectival), e.g., kšak/kščaśt 'bushy', džewo/džew'aśt 'of trees', gline/glin'aśt 'of clay', etc. For the latter category of suffixes, it is convenient to posit a floating segment with a palatal constriction (cf. Gorecka (1986), Gussman (1987)) which spreads onto the stem-final consonant, much in the same way that the palatal constriction of an underlying palatal vowel does.

The class of non-palatalizing suffixes consists of morphemes that can begin with /o/: /-ość/ (attribute), e.g., v'elki/v'elkość 'greatness', jasnt/jasność 'brightness', grubt/grubość 'thickness'; /-ov/ (adjectival), e.g., dom/domovt 'home', v'ek/v'ekovt 'century', bžozə/bžozovt 'birch'; and with /a/: /-ač/ (agent), e.g., b'leg/b'legəč 'runner', təpəč/təpəč 'catcher', /-av/ (adjectival), e.g., rudt/rudəvt 'reddish', šarok'/šarokəvt 'wide', tšt/tštəvt 'baldish'. In addition, there are a number of suffixes in Polish, which begin with palatal vowels, but do not palatalize the stem-final consonants. Here are some examples: /-i/ (Nom. plural), e.g., kot/kot't 'cat', žəbə/žəbt

¹ It would appear that the Tongue Blade is the default articulator in consonants with the palatal constriction; this point is taken up in more detail in the section on palatalization.

² Phonetically realized as /-əz/ or /-əz/ (word-finally).

'frog', noga/nog't 'leg'; /-em/ (Instr. sing., masc.) kot/kotem 'cat', pas/pasem 'belt', krok/krok'em 'step', etc.

The absence of palatalization before these suffixes can be explained under the assumption that palatalization is a cyclic rule (cf. Rubach (1984), and that affixes which begin with palatal vowels, but do not trigger palatalization, are non-cyclic.

Let us now go back to the discussion of suffixes /-k/, /-uś/, and /-un'/, with which we have opened this section. A brief look at the data in (45a-c) reveals that as far as the process of palatalization is concerned, these suffixes do not pattern with any other morpheme in the language: even if we tried to posit a floating palatal segment in the underlying representation of these suffixes, we could not explain the fact that they do not palatalize non-velar consonants.

A simple analysis of the process which affects stem-final velars before /-k/, /-uś/, and /-un'/, is available under the assumption that constriction location features are phonologically relevant. It is a phonetic fact that /k/, /g/, /x/, and /w/ involve a constriction in the velar region of the roof of the mouth. If we admit a phonological feature Velar Site, which characterizes all sounds articulated in this region, then, capitalizing on the fact that both the trigger and the target in the process of velar palatalization before /-k/, /-uś/, and /-un'/ are velars, we can explain this process as a dissimilation effect, triggered by the OCP applying on the velar tier. The dissimilation effect can be represented as follows:

(48) Velar Dissimilation; application: cyclic



Let us complete this analysis with some additional details. First, I assume that the Palatal Site specification is supplied by a default rule. Second, I assume that it is not necessary to analyze dissimilation as a process which deletes the entire velar constriction, even though that is what it appears to be on surface. On the assumption that predictable feature specifications may be absent from the Underlying Representation (cf. Archangeli (1984), Steriade (1987)), we may consider velar segments in languages that do not contrast fronted and ordinary velars, to have an underlying representation universally unspecified for the active articulator -- after all, they may be executed with Tongue Body only. Given this, we do not have to assume that the dorsal specification of the velar consonant imposes a limitation on the mechanism which supplies the default Site specification for the dissimilated consonant.

The dissimilation analysis of the data in (45) makes some very concrete predictions regarding the representation of affixes which may cause velar palatalization: it predicts that only suffixes which begin with a velar segment will ever trigger this process. This prediction appears to be a correct one: apparently, no Polish suffix that begins with a non-velar segment can selectively palatalize velars.

There now remains one last fact to account for: while it is true that all suffixes which trigger velar dissimilation begin with a velar segment, it is not the case that all velar-initial suffixes condition this process. For example, the suffix /-us/ (nominalizing)

does not palatalize any segment, e.g., *nagi/nagus* 'naked', *v'are/v'arus* 'soldier'. Also, as far as I can tell, no suffix that starts with /o/ palatalizes just velars (recall that according to the proposal made in this thesis, /o/ is represented as a complex segment with a velar, pharyngeal, and redundantly (cf. Stevens and Keyser (1989)) -labial constrictions). A plausible explanation for this gap might be that the dissimilation process applies in derived environments only, and that suffixes which do not trigger this process are non-cyclic. It is possible to defend these claims for the following reasons: first, velar consonants and velar vowels cooccur freely in underived environments (e.g., /kubet/ 'pail', /okulista/ 'optometrist', /guz'lk/ 'button', /xudv/ 'thin', etc.), second, the suffixes which do not trigger velar dissimilation, despite the fact that they meet the structural description of the rule, do not trigger any phonological rules, cyclic rules included.

Let us conclude the discussion of velar palatalization in Polish by stressing the relevance of this phenomenon to the claim that segments articulated in the velar region of the roof of the mouth do pattern alike in a phonological process. In order for the theory of phonology to be able to explain such phenomena in general terms, it must recognize the feature which can group the velar sounds into a natural class, the feature Velar Site.

3.4.2 Vowel Hardening in Kinyarwanda

A second argument for the feature Velar Site is based on a phenomenon which occurs in Kinyarwanda (segment inventory (Kimenyi (1979)): consonants: m, β, f, v, pf, t, d, n, s, z, ts, r, ʃ, ʒ, ɕ, c, ɟ, ɲ, ɕ, k, g, x; vowels: i, e, u, o, a, plus the same series with length), an Eastern Bantu language spoken in Rwanda and Burundi. The discussion that follows is based on the description of Kinyarwanda phonology by Kimenyi (1979).

Vowel clusters are disallowed in Kinyarwanda, and are eliminated whenever they arise as a result of the derivation. The method of elimination depends on the qualities of the vowels

involved in the cluster, on the quality of the preceding consonant, and often, on the morphological context. In what follows, I shall disregard morphologically circumscribed processes, and concentrate on purely phonological phenomena. The paradigm of these phenomena is outlined below.

When a non-low vowel is preceded by a consonant and followed by another vowel, it merges with the preceding consonant, forming a complex segment (cf. Sagey (1988) for the treatment of complex segments in Kinyarwanda) which retains the articulatory characteristics of the vowel. Back rounded vowel adds two constrictions* to the consonant: Velar/Tongue Body and Labial/Lower Lip*:

- (47) $tu + e:nga \rightarrow t^{w}e:nga$ 'we hate'
 $ku + dód + u + e \rightarrow kúdod^{w}e$ 'to be sewed'
 $ku + \beta on + u + e \rightarrow kú\beta on^{w}e$ 'to be seen'

Kimenyi notes (p. 12) that after the labiodentals (pf, f, v), the high back vowel is deleted, if it is followed by another vowel. This is shown below:

- (48) $ku + vu + e \rightarrow kuve$ 'to fall'
 $ku + pfú + e \rightarrow gúpfe$ 'to die'

I have not been able to find a single example that would show bilabials behaving differently from labiodentals. In fact, Kimenyi mentions two cases with /m/ and /β/ (p. 12), in which the first of the sequence of high back vowels also fails to become an obstruent, and is deleted instead. In the absence of more precise information, I assume that round vowels are always deleted between a labial consonant and a vowel.

A front vowel turns into a Palatal/Tongue Body constriction when it merges with the preceding consonant:

* I have been unable to find examples of /o/ turning into an obstruent. Since there are examples of the front mid vowel undergoing this process, I assume that the generalization stated by Kimenyi is correct.

- (49) $ku + se + e \rightarrow kus^o e$ 'to grind'
 $\beta l + o:ondo \rightarrow \beta l^o:ondo$ 'mud'
 $ku + r l + e \rightarrow kur^e$ 'to eat'
 $lm l + u:ga \rightarrow lm^u:ga$ 'professions'

Finally, the illustration of the behavior of the low vowel in a cluster with another vowel completes the paradigm. The low vowel /a/ is deleted whenever followed by another vowel, as shown below:

- (50) $be + re + u:bek + e \rightarrow bérú:bake$
 $n + za e:mer + e \rightarrow nze:mere$
 $be + e: + l: ker + i:r + je \rightarrow b\acute{f}ikoreje$ 'they worked for themselves'

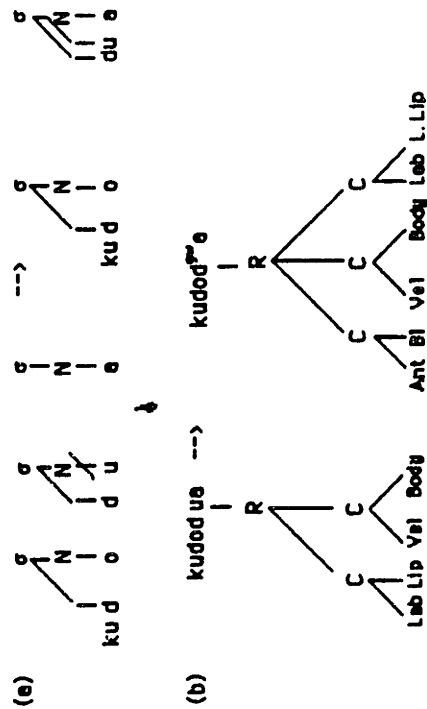
Kimenyi (1979) proposes the following analysis of the above data: first, non-low vowels are glided when followed by another vowel, then a consonant is inserted between the glide and the preceding consonant -- a palatal stop before the front glide, and a velar stop before the back glide. Finally, the inserted consonant assimilates in voicing and nasality to the preceding consonant, and the back glide fuses with the inserted consonant, while the front glide is deleted.

I adopt Kimenyi's position that there is a gliding process which precedes any other rule that is at work here. Most likely (although Kimenyi does not present the data that would help decide this issue), a word-initial non-low vowel turns simply into a glide when followed by another vowel. I analyze gliding as a process which resyllabifies with an onset, a vowel that has been demoted from the nuclear position.

Rather than proposing a consonant epenthesis, I follow Sagey's analysis of Kinyarwanda, and assume that the glide merges with the preceding consonant. The support for this view comes from the fact that, as pointed out by Sagey, and as illustrated by the data above, none of these alleged consonant clusters involves any given Site feature, or any given Articulator --tune more than once.

The processes posited above are illustrated in a sample derivation in (51):

(51) ku + dod + u + e --> kudodwe --> kudod^{wa}e 'to be sewed'



The analysis of Kinyarwanda proposed here relies on the model of feature representation in which only the vowels /i/ and /u/ share articulatory features with a palatal/dorsal, and a velar/dorsal respectively. By contrast, in the model of feature representation proposed in Sagey (1986), only the velar (and labial) consonants share articulatory features with vowels, as pointed out in 1.3. On that model, all cases of glide hardening and fusion in Kinyarwanda should yield a segment with a velar/dorsal component (see an elaboration of this point below).

On the constriction model, these phenomena are explained under the assumption that representations which contain clustered nuclei must be repaired to conform to the conditions on syllable structure in the language. Since Kinyarwanda allows only CV syllables, only complex segments may be allowed in the onset (cf.

Sagey (1986)), therefore, the offending vowels must be merged with consonants.

The reduction of /e/ and /o/ to /ɪ/ and /ʊ/ respectively requires an additional comment: in the present model, these vowels are represented as complex segments: /e/ has a Palatal/Tongue Body and Pharyngeal/Tongue Root constrictions; /o/'s constrictions are Velar/Tongue Body and Pharyngeal/Tongue Root. Since there cannot be glides fully homorganic with these vowels, we may assume that in the process of gliding, the Pharyngeal/Tongue Root constriction is deleted from both of these segments.

Finally, there remains the case of /a/: the absence of the merging effect with /a/ is perhaps due to the fact that glides homorganic to /a/ are either non-existent or very uncommon. The deletion of /a/ can be viewed as a default procedure whose purpose is the same as that of the gliding process: the removal of the hiatus.

The phenomenon of Kinyarwanda discussed above belongs among the so called strengthening/weakening processes, which affect stricture features, but leave the articulatory component of a segment intact. Such processes occur quite frequently, either in the form of a sound change, or as a phonological rule. An example of a process of weakening which provides us with additional evidence for a close articulatory match between the velars and the high back vowels is the g --> w change that occurred between Old and Modern English, e.g., bugar --> bow; lagu --> law, etc. (Lass (1971)).

Another example of a strengthening process is found in Kpan (i, e, u, o, a, plus a nasalized series of same; p, b, t, v, m, w, l, d, s, z, n, r, ts, dz, k, g, x, ʃ, ɲ, j) (a Yukonoid language discussed by Shimizu (1971)). In Kpan, front glide turns into a palatal coronal fricative after the labials and the back rounded glide turns into a velar stop (without rounding) after any consonant except a velar. After a velar, the back rounded glide surfaces as a labial. The newly derived consonants agree in voicing and nasality with the segment that precedes. (Unfortunately, no data are quoted by the author.)

This phenomenon is very reminiscent of the process which merges a vowel with a consonant in Kinyarwanda, with an interesting twist: here, the front glide does not give a rise to a palatal dorsal, but changes into a coronal segment instead. Of interest here is the fact that this process preserves the original constriction location of a glide, but not the active articulator. If this observation were to be generalized to the entire paradigm, the conclusion for Kpan would be that only the original constriction location is preserved in the strengthening process, and that the active articulator is assigned by a default rule.

Finally, a morphologically conditioned glide/consonant alternation occurs in Fula (i, e, u, o, a; p, b, ɸ, β, m, ɓ, s, t, d, n, l, r, ɗ, ʒ, ɗ, ɲ, k, g, ŋ; every segment can be geminated; Ruhlén (1975)), where depending on the grade, a back glide surfaces as either a back glide, a labial stop, or a velar stop (Lieber (1984)).

All of the above examples indicate an intimate relationship between the consonants commonly referred to as "velars" and the high (mid) back vowel, a relationship, which an adequate system of phonological representation should be able to express.

One could conceive of treating the strengthening processes within Sagey's articulator model by making use of the height and backness features -- the dependants of the Dorsal Articulator. However, such an analysis faces some serious difficulties. The first difficulty arises in connection with the phonological representation the articulator model assigns to the plain velar consonants: In order to account for the fact that plain velars never block dorsal harmony, regardless of the harmonic feature, Sagey (1986) proposes that /k/, /g/, /x/, /ŋ/, etc., be represented with the bare Dorsal Node. I agree with Sagey that the behavior of velars in vowel harmonies is a phonological fact that must be accounted for, and I adopt her treatment of velars, to the extent that it can be incorporated into the model I am proposing: I assume that velars are represented with the Tongue Body constriction at the Velar Site, and that the Tongue Body is not modified by any features.

Within the articulator model, representing velars with an unmodified Dorsal Node has the effect of making these consonants "generic" dorsals, which have as much in common with the high back vowels as they do with any other dorsal segment, and that category covers all vowels on the Sagey model. On that model, there is no reason why, in Kinyarwanda, the vowel /a/, or for that matter, any vowel, should not turn into a velar (dorsal) element. Structure preservation cannot be of help here, as it does not prevent /e/ and /o/ from gliding. Therefore, the unique relationship between /u/, /o/ on the one hand, and the velar articulation on the other hand, cannot be explained on this model.

Another difficulty in appealing to the dorsal features for the purpose of explaining the vowel/glide/consonant alternations, has to do with the task of representing the palatal dorsals, and the palatal/dorsal articulations in a complex segment. Presumably, the articulator theory would have to treat these sounds as dorsal segments with [-back] specification. However, evidence from languages which contrast palatal stops* and fronted velars on surface (e.g., Basque, Macedonian, etc.), suggests that this is not a possible solution. This topic is discussed in more detail in chapter 6.

Let us conclude on the basis of the above, that the unique similarities between high back vowels and velar consonants cannot be explained on the articulator model, but they are predicted by the model of feature representation which recognizes the phonological status of the velar point of articulation.

* The phonological status of palatal dorsals is discussed in more detail in section 6.2.

3.5 Pharyngeal Site

The feature [pharyngeal], in the sense that will be used here, has been introduced to the theory of phonology by McCarthy (1989), in a comprehensive, revealing study of the so called "gutturals". Consonants articulated with a constriction in the uvular, pharyngeal, or laryngeal region of the vocal tract.

McCarthy's discussion of the feature [pharyngeal] is based on the phonological material of the Semitic languages, where the gutturals occur commonly, and in great variety of phonemic contrasts. In his study, McCarthy shows that the gutturals pattern as a natural class in a number of phonological processes: they have a lowering effect on the adjacent vowels, they are subject to restrictions on syllabification to which no other segments are subject, and they appear to be transparent to some vowel assimilation processes. We shall discuss some of these phenomena later on in this section.

McCarthy argues convincingly that the articulator-based theory of feature representation has no means of explaining the fact that gutturals pattern as a natural class, as the three classes of segments: uvulars, pharyngeals and laryngeals do not share an active articulator in the same sense that coronal or labial sounds do. He points out that "the gutturals are produced by three entirely distinct gestures: a purely glottal one in the case of the laryngeals, retraction of the tongue root and epiglottis and advancement of the posterior wall of the laryngopharynx in the case of the pharyngeals; and a superior-posterior movement of the tongue dorsum in the case of uvulars".

He also dismisses a possibility that the gutturals might be characterized with a unique acoustic feature: "On the acoustic side, the gutturals are also quite diverse. The laryngeals theoretically have the resonances of a uniform tube (though in practice, they simply adopt the properties of the vocalic context). The pharyngeals

have a very high first formant, but the uvulars raise the first formant only slightly above the value for a uniform tube. Both uvulars and pharyngeals have a low second formant".

McCarthy considers earlier treatments of point of articulation features in phonology: Jakobson, Fant and Halle (1951), Chomsky and Halle (1968), Ladefoged (1975), Williamson (1977), and concludes that none of these frameworks are capable of characterizing the guttural consonants as a natural class. The feature [flat] of Jakobson et al., defined acoustically as equivalent to the low second formant, can classify uvulars and pharyngeals together, but leaves out the laryngeals.

The SPE framework, while technically capable of characterizing gutturals as a natural class (: [-high, -anterior]), can do so only at the cost of drastically redefining the feature [high]: in SPE, the articulatory basis of this feature has been vertical displacement of the tongue body from its neutral position. However, as McCarthy points out (and before him, Kenstowicz and Kisseberth (1979)), the tongue body does not participate in the production of pharyngeals or laryngeals. Also, McCarthy observes, the uvulars, while grouped with the rest of the gutturals by [-high] in the SPE framework, are articulated with a high tongue position. These clashes between the phonological representation and the articulatory reality lead McCarthy to reject the SPE approach to representing the gutturals.

Finally, McCarthy shows that Ladefoged's (1975) and Williamson's (1977) theories of multi-valued point of articulation features are also incapable of treating the gutturals as a natural class, because in these theories, uvulars, pharyngeals and laryngeals are characterized by three different features, corresponding to three different constriction locations.

In order to reconcile the phonological facts about the gutturals with an assumption that place features must have an articulatory basis, McCarthy introduces the feature [pharyngeal], whose

articulatory counterpart is the region between the uvula and the larynx. This feature characterizes gutturals as having the same constriction location.

McCarthy proposes to incorporate [pharyngeal] into the model of feature representation of Clements (1985)/Sagey (1986) in such a way, that it represents one more place feature, dominated by the Place Node, and hierarchically equivalent to the Coronal, Labial and Dorsal Nodes.

In the framework developed in this thesis, McCarthy's feature [pharyngeal] fits elegantly with the rest of the Site features: it represents a constriction location, along with the Labial, Anterior, Palatal and Velar Sites.

With the results presented in McCarthy (1989), the task of arguing for the Pharyngeal Site is virtually completed. However, since the status of this feature in the constriction model is rather different than in the modified articulator model proposed by McCarthy, an analysis of the "guttural" phenomena which accounts for these differences seems necessary.

The main difference between McCarthy's proposal and mine is that on the constriction model, vowels articulated in the pharyngeal region are included among the natural class characterized by the Pharyngeal Site. This is a consequence of the fact that in this model, the constriction location must be represented in vowels as well as in consonants. On this view, the class of pharyngeal sounds includes ?, h, ʕ, x, ɣ, R, G, etc., as well as a, o, e, ɔ, ε. Indeed, the phenomena that McCarthy discusses point directly to the conclusion

* Recall from the introduction that /a/ is represented with a Tongue Root constriction at the Pharyngeal Site, and /e/ and /o/ are analyzed as complex segments, /e/: Palatal/Tongue Body, Pharyngeal/Tongue Root; /o/: Velar/Tongue Body, Pharyngeal/Tongue Root. Again, this way of representing vowels will be independently motivated in chapter 5, however, some of the facts on the basis of which we shall argue for the phonological constituency of the feature Pharyngeal Site, can also be read as evidence for these representations.

that the non-high vowels and the pharyngeal consonants form a natural class.

In the remainder of this section, I review several cases that McCarthy discusses in his paper, and I show that they can be given an analysis consistent with the model that is being proposed in this thesis.

3.5.1 Vowel Lowering in Tiberian Hebrew*

McCarthy discusses the following phenomenon in Tiberian Hebrew (segment inventory (Prince (1975), who follows Lambdin (1971), and Gesenius (1910)): i, u, e, o, (ə), a, i:, u:, e:, o:, a:, p, (f), b, (v), m, t, (θ), θh, d, (ð), s, ʃ, ʒ, n, l, j, k, (x), g, (ɣ), w, q, r, h, ʕ, ? , h; the diacritic " " indicates the so called "emphatic" or pharyngealized consonants.): there is a group of noun stems in the language (referred to as the "segholate" nouns in Hebrew linguistic tradition), whose surface forms alternate between the CVCVC shape in word-final position and the CVCC shape before a vowel-initial suffix, e.g., the underlying /malk/ 'king' surfaces as /mélek/ when unsuffixed, and as /malk/ (e.g., /malk-i/ 'my king') when followed by a vowel-initial suffix. There are good reasons to believe that the vowel which appears between the last two consonants of the stem is epenthetic: first, it fails to attract stress (ordinarily, if the last syllable of a word ends in a consonant in Biblical Hebrew, it is stressed (Rappaport (1981))), and second, its quality is predictable: it surfaces as /a/ when adjacent to a guttural consonant, and as /e/ elsewhere. The following are examples in which the epenthetic vowel is adjacent to a guttural:

(52)(a)	/baht/	-->	báht	'costly stone'
	/baʕ/	-->	báʕ	'master'

* I am grateful to John McCarthy, Alan Prince and Brian Sletsmo for discussing this phenomenon with me. Any errors in the interpretation of the data, and in the analysis are mine.
* a/e alternation is discussed below.

- (b) /bath/ --> bə'təh 'name of city'
 /bals/ --> bə'las 'swallowing'

Following Malone (1984), McCarthy analyzes the a/e alternation in the first syllable of the forms in (52b) as a reflex of a more general assimilation rule which raises /a/ to /e/ when in an open syllable and followed by /e/. He also assumes after Malone that there are two processes of vowel lowering in the guttural environment, both applying after the rule of epenthesis: one process affects vowels after the gutturals, and it takes place before the rule of vowel raising just mentioned, the second one follows the raising rule, and affects the vowels in front of the gutturals.

The analysis that I propose is also based on the assumption that there are two processes which derive low vowels in (52). First, I analyze the process of epenthesis as insertion of a schwa: a vowel whose constriction location is unspecified. Let us represent this process as follows:

$$(53) \quad \emptyset \rightarrow R \quad / \text{C} ___ \text{C}\#$$

|
 Constr
 |
 Dorsal
 |
 -high

Since the schwa is [-high], the raising of /a/ to /e/ in the first syllable of the segholate nouns can be attributed to the spread of the height specification of the epenthized vowel. (I shall postpone the discussion of the exact mechanism which accomplishes the /a/ --> /e/ change until the time when I discuss the processes affecting the Tongue Body features (chapter 5)).

* Recall from 3.3.1, that on the basis of Fent's (1960) characterization of the schwa as a vowel with a fairly large opening, and on the assumption that the high tongue body position is associated with a small aperture, I proposed to represent it phonologically as a [-high] vowel.

The "lowering" effect the guttural environment has on the inserted vowel is best analyzed as the spread of the Pharyngeal Site of the guttural consonant onto the Constriction Node of a schwa, a vowel which lacks the Site specification. This direction of analysis is supported by two facts: first, the underlying /e/ does not undergo the process of "lowering", e.g., he + ʕbl:r --> heʕəbl:r 'he led across', which suggests that /a/ in the segholate nouns is not derived from /e/ via a lowering influence of the gutturals. Incidentally, the representation which I propose for the vowel /e/ rules out a possibility of such a process: /e/ is a complex segment with a Tongue Body constriction at the Palatal Site and a Tongue Root constriction at the Pharyngeal Site. This makes it already a pharyngeal vowel. The only means for /e/ to become /a/ is through the deletion of the palatal constriction. Second, as discussed by Prince (1975), p. 98, the lowering of schwa in the guttural environment is a more general process, not limited to the epenthetic vowels. According to Prince, all schwas in the language turn to /a/ in the guttural environment*. Accordingly, I propose to represent the process of pharyngeal spreading as follows:

$$(54) \quad \begin{array}{c} R \quad R \\ | \quad | \\ \text{Constr.} \quad \text{Constr.} \\ \text{Phar} \quad \text{T. Body} \end{array}$$

Note that the phenomenon observed here in some ways parallels the phenomenon of schwa palatalization in Russian and in Margi, in section 3.3: in both cases, segments with different Articulator specifications, but with identical Sites, trigger a phonological change which can be treated only in terms of an assimilation to the constriction location.

* Although, Prince notes only cases of /e/ lowering after a guttural, not before. Given limited data, I have not been able to determine whether all schwas are affected before the gutturals.

Following Malone's (1984) and McCarthy's (1989) insight, I assume that there are two processes which spread the Pharyngeal Site: the rightward spread, responsible for the data in (52a), which precedes the raising rule mentioned above, and the leftward spread, responsible for the facts in (52b), which follows the raising rule. This assumption accounts for the fact that the epenthesis vowel triggers the raising of /a/ in the preceding syllable only when it is followed, not preceded by a guttural. Presumably, following the spread of the Pharyngeal Site, the resulting segment is reanalyzed as /a/: a segment which lacks any height specification (see chapter 5). Such a segment may not trigger the raising rule.

There now remains the matter of explaining why the epenthesis schwa surfaces as /e/ instead of /ə/: after all, there have been schwas in the phonetic representation of Biblical Hebrew, cf. Prince (1975). The answer to this question is given in Prince (same). First, Prince observes that there are other occurrences of epenthesis in the language: he notes the forms like /gabu:/ 'boundary', /berit/ 'covenant', etc., in which the presence of a schwa cannot be attributed to vowel reduction. Prince concludes that the occurrence of schwa in these forms is due to the process of epenthesis, which indeed inserts a schwa, not /ə/, into a word-initial or word-final consonant cluster. He attributes the fact that the epenthetic vowel surfaces as /e/ in the "segholate" nouns to a process which spells out /e/ as /ə/ in word-final closed syllables.

Let us summarize the discussion of schwa pharyngealization in Tiberian Hebrew with a sample derivation, to illustrate the main points of the analysis:

(55) Underlying form:	/malk/	/beht/	/beles/
Gloss:	'king'	'costly stone'	'swallowing'
Epenthesis:	málek	béheṭ	béles
Rightward Pharyng.	n.s.	bə'həṭ	n.s.
a --> ə	mélek	n.s.	béles
Leftward Pharyng.	n.s.	n.s.	béles

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ə --> e / __C#

mə'lek n.s.

I conclude on the basis of the Tiberian Hebrew facts discussed above, that segments (both consonants and vowels) articulated with a constriction in the pharyngeal/laryngeal region of the vocal tract pattern as a natural class. These facts argue for the phonological constituency of the feature Pharyngeal Site.

3.5.2 Ablauting Vowels in Arabic

The phenomenon that I consider next, the Arabic ablaut, has been discussed earlier by Brame (1970) and McCarthy (1989). The analysis proposed here develops some of the ideas suggested in these works.

In Standard Arabic (phonetic inventory according to Maddleson (1984): t, u, e, o, æ; l, o, a; b, m, w, f, t, d, ð, s, z, n, l, r, c, tʃ, dʃ, sʃ, zʃ, dʒ, ʒ, j, k, g, q, x, h, ʕ, ʔ, h; length ignored) the perfective and imperfective templates of the verbs in Form 1 are CVCVC and CCVC respectively. Brame (1970) proposes to derive the CCVC template of the imperfective via a rule of vowel elision. He notes that while the perfective stems (CVCVC) are always suffixed, the imperfectives are always preceded by a prefix that ends in a vowel. This process creates an environment for the application of the elision rule, which he formulates as follows: V --> Ø / V + C__CV.

The first vowel of the stem in the perfective is always /a/. The root consonants remain the same between the templates. If we adopt Brame's proposal, and derive the imperfective template via an elision rule, we are left with only one difference between the two aspects: the difference in the quality of the last vowel of the stem. On the basis of the vowel alternation observed in that position in the two aspects, the verbs of Arabic are divided into five ablaut classes:

(56) a/u	katab/ktub	'write'
a/i	dʕarab/dʕrib	'beat'
i/a	šarib/šrab	'drink'

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a/a	fəʔel/fəʔel	'do'
u/u	baʔud/baʔud	'be stupid'

McCarthy (1989) characterizes the ablaut classes as follows: the occurrence of verbs in the u/u class, and partially in the i/a class, is either semantically or morphologically determined, the occurrence in the a/i or a/u class is entirely unpredictable, and finally, the a/a class consists of verbs which have a guttural consonant adjacent to the ablauting vowel.

The view of ablaut offered by Brame (1970) is somewhat different. Brame too characterizes the u/u class as morphologically circumscribed, but proposes to treat the perfectives and imperfectives of the remaining classes as phonologically related. He observes for example, that the height of the last stem vowel in the imperfective is always (outside the w/u and a/a classes, of course) opposite of the height of the last stem vowel in the perfective. He proposes to derive the vowel of the imperfective by a rule which polarizes the height of the underlying vowel -- the vowel which appears in the second position in the perfective. This proposal works elegantly for the a/i class, but encounters a problem when applied to the a/i and a/u verbs: if the vowel of the imperfective is indeed derived from the vowel that surfaces in the last stem position of the perfective, how can /i/ and /u/ in the imperfectives of these verbs be predicted?

Brame considers a possibility that there might be two low vowels in the underlying inventory of Arabic: a front vowel, which surfaces, and the back vowel, which merges with /æ/ on surface. When polarized, these vowels would yield /i/ and /u/ respectively in the imperfective forms. He rejects this possibility on the grounds that nothing else in Arabic phonology requires positing /a/ in the underlying representation. Instead, Brame proposes to represent the stems of the a/u class with a diacritic +F, and he posits the rule of height polarization which associates [+round] with +F (Brame (1970), p. 157).

I suggest a way of looking at Arabic ablaut which captures some of Brame's insights, but derives vowel quality in a/u, and a/a classes from the consonantal environment, and treats the a/i class as a default.

It has been long noticed about Arabic, that the appearance of /a/ in the imperfective is contextually determined: /a/ appears if one of the adjacent consonants is a guttural. This is shown below:

(57)	qəʔəʔ-ət	'she cut'	tə-qəʔəʔ-u	'she cuts'
	fəʔəh-ət	'she opened'	tə-fəʔəh-u	'she opens'
	baʔəʔə-ət	'she sent'	tə-baʔəʔə-u	'she sends'
	qəʔəʔ-ət	'she read'	tə-qəʔəʔ-u	'she reads'
	ʔəhəb-ət	'she went'	tə-ʔəhəb-u	'she goes'

According to McCarthy (1989), out of 436 verbs which ablaut in /a/ (have /a/ in the imperfective), 411 contain a guttural consonant adjacent to the vowel. Of the remaining 25, 15 have a guttural in the initial position.

Within the guttural class, the uvulars /x/ and /ħ/ behave with some uncertainty: frequently, they do trigger the a-ablaut (e.g., /ħəxəħə; a/ 'to preserve', /ħəħəxə; a/ 'to splinter', /baħəħə; a/ 'come unexpectedly'), but almost as often, they appear with the a/u class, e.g., /ħəħəħə; u/ 'be void', /naħəħə; u/ 'pick', /rasəxə; u/ 'be stable', etc. This fact is noted by McCarthy (1989), p. 13. /q/ is virtually excluded from the guttural class, in that it almost never triggers the a-ablaut. Instead, it tends to associate with the a/u verbs.

The phonological properties of the a/u class are not as transparent as the properties of the a/a class, yet on closer examination, clear generalizations emerge. The results which I am about to discuss are rather informal, based on a casual reading of

*This example is quoted from Wehr's (1971) dictionary, in which verbs are entered with the perfective form followed by the vowel of the imperfective. Rather than citing full imperfectives, I follow the format adopted in the dictionary.

Wehr's (1971) dictionary. I have compiled a list of a little over 800 tri-literal verbs that belong to either a/u or a/i class, guided by the main entries in the dictionary. Roughly, about five hundred of these are a/u verbs. The presence of the vowel /u/ in the imperfective is usually associated with an adjacent uvular, velar, or labial consonant. I found 44 cases (not counting the cases with /r/; see below) in which /u/ appears without such an environment; of these, 29 roots have a velar, uvular, or a labial as their first consonant. These are some of the examples of a/u verbs, contrasted with the examples of a/i verbs:

(5a)(a) a/u:

naḡama; u/i	'hum'
ṭaḡara; a/u	'open'
naḡala; u	'sift'
maḡala; a/u	'blow nose'
naḡaḡa; u	'deliver'
ṣaḡala; u	'try'
naḡasa; u	'turn around'
saḡana; u	'be still'
naḡaḡa; u	'help'
ṣaḡama; u	'test'

(b)

ṣaḡama; i	'hesitate'
naḡafa; i	'tease'
ḡaḡama; i	'wrap'
ḡaḡama; i	'sever'
ḡaḡara; i/u	'surround'
ḡaḡaba; i	'gather firewood'
ḡaḡama; i	'destroy'
ṣaḡaba; i	'cross arms'

The presence of /u/ seems to be required especially when any of these consonants precede the ablauting vowel: for example, out of 124 a/u and a/i radicals with either /k/, /g/ (which surfaces as /dʒ/ in Standard Arabic, cf. Brame (1970), McCarthy (1989)), /q/, /x/, or /ḡ/ in the second position, 106 ablaut in /u/. And out of 125 a/u and a/i radicals with /b/ or /m/ in the second position, 99 have the ablaut vowel /u/. In the third position, the velar and uvular consonants still have a strong influence in determining the quality of the ablaut vowel (out of 99 stems, 78 have /u/ in the imperfective); the influence of the third position labials is perceived in about 50% of the cases.

While the numbers quoted above could hardly be a result of a free and unrestricted distribution of segments, it is also far from obvious that we are dealing here with a productive phonological process. After all, there exist a considerable number of exceptions to every generalization stated above. A plausible explanation for this situation might be that the phenomenon which we observe in Standard Arabic is a reflex of a phonological process possibly productive in the past, but becoming lexicalized in the modern language, or else, an ongoing process. For one thing, a large number of doublets (168 in my sample of a/i and a/u verbs) suggests that Arabic ablaut is in a state of transition. A comparative historical analysis might reveal the direction of the change. However, for the purpose of the present discussion, the exact history of the phenomenon is not as important as is its mechanism, and this is what I turn to next.

In order to account for the fact that the vowel /a/ of the perfective surfaces as either /a/, /u/, or /i/ in the imperfective, I would like to suggest the following: the stem-final vowel /a/ is pruned of its articulatory features, the Articulator and the Site, in the imperfective. In fact, we may assume that this vowel is a morphological marker of the imperfective. This aspect of the analysis is crucial in that no other /a/'s of the language are affected in the way this vowel is.

The resulting segment assimilates in Site to an adjacent consonant: labial, velar, uvular, pharyngeal, or laryngeal. In the case of a labial, it assimilates to the Labial Site, producing /u/, in the case of the velar -- to the Velar Site, and the output is /u/. A uvular may spread either the Velar or the Pharyngeal Site (on the assumption that uvulars are complex segments, cf. McCarthy (1989), and the discussion in chapter 6), producing either /u/ or /a/ respectively, and the remaining gutturals may spread the Pharyngeal Site, producing /a/.

When an assimilation fails to apply, the unspecified vowel surfaces with the default melody /U/. This appears to be the correct way of viewing the a/i class (rather than, for example, attributing /U/ to an assimilation in the constriction location of the coronal consonants) for the following reasons: first, /U/ is the melody of the epenthetic vowel in Arabic; second the largest number of exceptions to the distributional generalizations stated above is found among the a/i verbs. This is best explained as an application of a default rule applying when, for some reason, the phonological rule fails to apply.

The above analysis accounts for the distributional generalizations sketched out above, and offers a plausible explanation for the fact that uvulars can pattern with either velars or pharyngeals/laryngeals. Unfortunately, it gives us no clue as to why the fricative uvulars (/x/ and /ʁ/) do pattern both ways, but /q/ patterns with velars only. I leave this question unanswered.

During the discussion of the environments which condition the ablaut, I have left out of the consideration /r/, the segment which in Standard Arabic surfaces as an alveolar trill (Brame (1970)). In about two thirds of the verbs, /r/ patterns with the consonants which are associated with the a/u class. Because of the frequent occurrence of /r/ in Arabic, this makes for a significant number of cases (59) which appear to violate the generalization laid out above, and makes /r/ the only coronal consonant which regularly triggers the /u/ ablaut. This, of course, is not the only problem caused by /r/.

because there is also a large number of /r/'s which do not trigger the /u/ ablaut. Therefore, we are faced with the task of explaining why some tokens of a given sound trigger certain phonological behavior (assuming that the above generalizations are to be treated in phonological terms), and others do not.

A similar situation arises w.r.t. /l/, also left out of the consideration so far: /l/'s divide evenly among the a/u and a/i cases. Conceivably, this behavior could be attributed to the fact that /p/ merged with /l/ in the history of Arabic (Brame (1970)). It could be hypothesized that the present situation reflects that moment in the history of the language when both segments coexisted, and when the rule of ablaut distinguished between the segments with the labial constriction location (/p/, /b/, /m/), and other segments (/l/ among them).

Extending the same approach to the /r/ cases, plausibly, the modern day /r/ could be derived from a historical /ʁ/ (a uvular trill) (such a possibility is not ruled out by the semitacists, cf. Moscati (1984), p. 32). With this hypothesis, it is reasonable to assume a period in the history of the language when the ablaut rule had to distinguish between the two representations. The cases of modern /r/ appearing in the a/u verbs could be attributed to the spreading of the /ʁ/'s velar component, and the cases in which /r/ appears in the a/i verbs, could be derived from an underlying /r/. In the latter, the melody of the ablaut vowel would be derived via a default rule.

Let us conclude the discussion of Arabic ablaut with this comment: the primary importance of the ablaut phenomena, and the reason for considering it here, lies in the fact that it groups the guttural consonants (modulo the behavior of /q/) into a natural class, thus providing an argument for the feature [pharyngeal] proposed by McCarthy (1989). I have extended the discussion to

* Although John McCarthy (p.c.) suggests that more likely, the /ʁ/ of Hebrew developed from the common source /r/. On the interpretation I am suggesting, /ʁ/ would be the reconstructed segment for the Semitic languages, and /r/ would be a new development in Arabic.

include the rest of the paradigm in order to show that McCarthy's feature [pharyngeal] patterns together, or at least did pattern at some point in the history of Arabic, with other features which refer to the constriction location: Labial and Velar in this case. Therefore, the ablaut in Arabic provides evidence for the status of [pharyngeal] as another site feature in the model of phonological representation proposed in this thesis.

3.5.3 Vowel Lowering Before Uvulars in Greenlandic Eskimo

I now turn to vowel lowering phenomena of Greenlandic Eskimo (segment inventory after Maddieson (1984): l, u, a.(e), (o); p, β, m, f.; t, t̥, n, ɲ, ts, s, š, k, x.; ɣ, ŋ, q, x.; a) discussed earlier by Kenstowicz and Kisseberth (1979). In West Greenlandic, only non-high vowels are found before uvulars /q/, /x/, and /ʁ/:

(59)	seameq	'glacier'	neadloq	'goose'
	iseaq	'ankle'	ipeaq	'herpoon strap'
	qaceloq	'bark'	nanq	'beer'

No other consonant in the language has a lowering effect on the vowels:

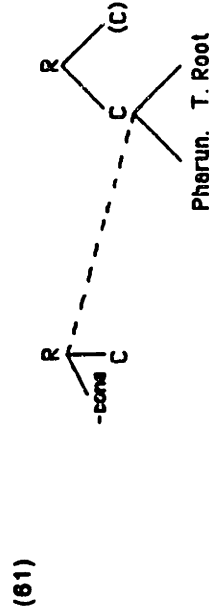
(60)	nuna	'land'	ikusk	'elbow'
	ugak	'cow'	ipnaq	'bluff'
	igdio	'house'	iga	'pot'

An analysis of the above phenomenon within the articulator model is technically possible, under the assumption originally suggested in SPE, that uvular consonants and vowels /e/, /o/, and /ə/ share the feature [-high]. In fact, Kenstowicz and Kisseberth's analysis of the Greenlandic Eskimo data follows this avenue. However, as pointed out by McCarthy (1989), uvulars are definitely not [-high] articulatorily-wise. In fact, if these segments were to be characterized in terms of height, and if the height feature were to have any phonetic content, then, given the articulatory description

* Vowels are also lowered in word-final position.

of these segments in McCarthy (1989), they could only be characterized as (perhaps redundantly) [+high].

The constriction model affords a simple and elegant account of vowel lowering in Greenlandic Eskimo: First, following McCarthy's suggestion, I assume that uvulars are complex segments. Incorporated into the constriction model, this suggestion translates as follows: uvulars have a Tongue Body constriction at the Velar Site, and a Tongue Root constriction at the Pharyngeal Site. The Tongue Root/Pharyngeal constriction spreads onto the Root Node of the preceding vowel in the manner suggested below:



The output of this rule is a complex vowel: either a palatal/pharyngeal /e/, or a velar/pharyngeal /o/.

A process that is a mirror image of the one in Greenlandic, occurs in Chemehuevi (inventory according to Press (1980): t, t̥, u, o, ə; the same series with length; p, β/v, m m̥, w, w̥, t, s, ts, r, n, n̥, ʃ, ʃ̥, k, ɣ, ŋ, p̥, k̥, ɣ̥, ŋ̥): before /o/ or /ə/, a voiceless velar turns into a uvular: tka + ŋu + aka --> tikanuq 'that you eat' (the velar remains unaffected). Again, an analysis of this phenomenon is straightforward within the constriction model: on this model, all non-high vowels are represented with a pharyngeal constriction. In Chemehuevi, the pharyngeal constriction spreads onto a voiceless velar; the resulting segment is a consonant with a Velar/Tongue Body and Pharyngeal/Tongue Root articulations, in other words, a uvular.

The relevance of the above phenomena to the argument made in this section is clear: since the non-high vowels are represented with

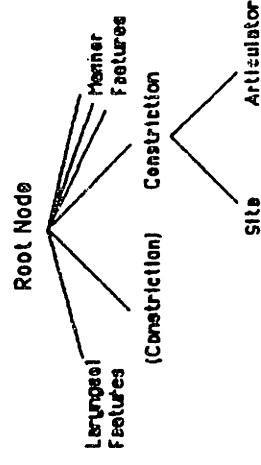
a pharyngeal component in the constriction model, they are assumed to form a natural class with the guttural consonants. Therefore, processes such as vowel lowering before uvulars in Greenlandic, or pharyngealization of /k/ before non-high vowels in Chemeheuevi constitute support for the feature Pharyngeal Site, because they show that the non-high vowels and the gutturals pattern alike.

4. Site and Articulator Within the Phonological Tree: The Constriction Node

Having established the existence of both Site and the Articulator features, we are now faced with the task of incorporating these features into the theory of phonological representation. As far as the larger picture is concerned, I adopt the theoretical framework introduced by Clements (1985) and Sagey (1986), whose success in the recent years testifies to its basic correctness. I adopt such elements of the Clements/Sagey structure as the Root Node and the Laryngeal Node, and I assume along with Sagey (1986) that the manner features are directly dominated by the Root Node. Finally, I follow Piggott (1987) and McCarthy (1988) in including [nasal] among the features dominated by the Root Node. With the above, only the articulatory features remain left out of the segmental tree.

Throughout this presentation, I have been assuming without argument a structure in which the Site and the Articulator features are dominated by a constituent which I have named the "Constriction Node", and which I have represented as a dependent of the Root Node, as repeated below:

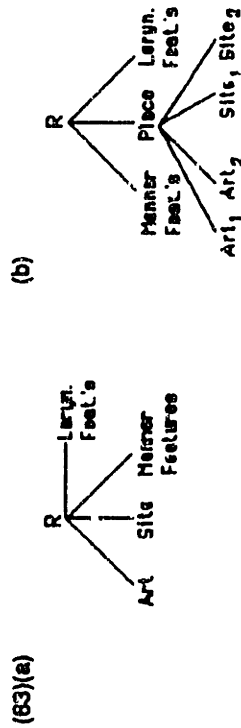
(82)



Intuitively, the constituency of such a node is easy to accept, as it represents the articulatory gesture necessary in the production of a speech sound. The physical parameters of this gesture are indeed the

site of the maximum narrowing and the organ which executes it". However, from the phonological point of view, the need for such a constituent remains to be established. The present section is devoted to this goal.

Granted that we do need features which represent the location and the articulator active in the constriction, we are left with at least two options other than (62) for representing these features: we can assume that both Site and the Articulator are directly dominated by the Root Node; or we can posit a constituent equivalent to the Place Node of the Clements/Sagey model, dominating all Articulators and all Sites with no other node intervening. The two options are represented in (63a) and (63b) respectively:



(The tree in (63b) is designed to represent a complex segment on purpose: as we shall see, only when the complex segments are considered, will the difference between the model which assigns a separate node to every articulation (=constriction), and the model in which all articulations are combined under one node, become evident.)

Let us now consider the above proposals in turn. The model in (63a) is a transparent straw man: given that non-constituent spreading is not allowed (cf. Steriade (1987)), this model makes equally impossible processes which spread, say, an Articulator and the laryngeal features, and the so called "point of articulation

* As well as the aperture, but we do not address the phonological status of the stricture features, nor their place in the representation of a segment, in this thesis.

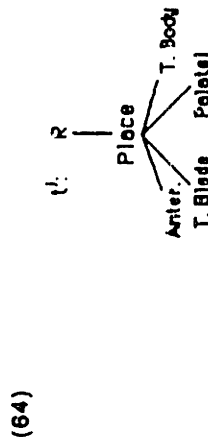
assimilations", which involve spreading of the Site and the Articulator together (e.g., nasal assimilation to a following obstruent).

The model in (63b) cannot be dismissed as easily; therefore, it is discussed at greater length in the next section.

4.1 The Constriction Model vs. The Model with a Place Node Dominating Sites and Articulators

When segments with single articulations are considered, the model in (63b) renders point of articulation assimilations as natural as does the constriction model: it treats these assimilations in terms of the Place Node spreading, while the constriction model treats them as the spread of the Constriction Node.

The differences between the two representations become apparent in the case of processes that involve complex segments. Consider, for example a complex segment such as /tʰ/: the model in (63b) assigns the following representation to it (the laryngeal and manner features are omitted):



Since this model does not preserve the distinctness of the Anterior/Tongue Blade and Palatal/Tongue Body articulations, it predicts, given the assumption that only constituents may be spread by phonological rules, that the processes which spread together the nodes Palatal and Tongue Body of /tʰ/ should be as unusual as, say, the processes which spread together the nodes Palatal and Tongue Blade of /tʰ/. While I know of no example of a process converting a segment to /tʰ/ before /tʰ/, processes in which one of the

articulations in a complex segment spreads are not uncommon. Let us consider an example of such a process, involving palatalized segments in Polish.

4.1.1 Palatalization Spread in Polish

Polish has a very well motivated rule which palatalizes Anterior sibilants (/s/, /z/) before palatalized segments:

- (65)
- | | | |
|-----------|----------|----------------------|
| most | mośće | 'bridge' |
| snu | śnie | 'dream' |
| spać | śpi | 'to sleep/he sleeps' |
| 'organism | organizm | 'organism' |

It is not the case that palatalization spreads onto a sibilant only if the cluster is followed by a front vowel: with an exception of sequences separated by the prefix juncture (which are immune to most phonological processes in Polish), sequences of /s/ (/z/) followed by a palatalized segment are virtually excluded from the language. Consider the following examples:

- (66)
- | | | | |
|---------|-----------|--------|------------|
| ścane | 'well' | śm'ech | 'laughter' |
| ściewać | 'to sing' | kaźń | 'torture' |
| bojaźń | 'fear' | kość | 'bone' |
| miłość | 'love' | waśń | 'quarrel' |

At least for some of these cases, the fact that palatalization of /s/ must be derived via a spreading rule can be proven: Polish has a depalatalization rule, which affects a stem-final palatalized consonant before a consonant-initial suffix, for example:

- (67)
- | | | |
|--------|-----------|------------|
| hrab'a | hrap-sk-i | 'count' |
| śań | śon-k-e | 'anteroom' |

* Recall from 3.2.3 that /s/, /z/, /c/, etc., are surface manifestations of underlying /s'/, /z'/, and /t'/ respectively.

This rule must precede the spread of palatalization, because the sibilant which precedes the underlyingly palatal segment also surfaces unpalatalized:

- (68)
- | | | | |
|--------|-----|----------|--------------|
| kość | but | kost-ko | 'bone' |
| miłość | but | miłostko | 'love/illrt' |

It is not the case that all stem-final sequences of palatalized segments are depalatalized before a consonant-initial suffix; in the case of underlying sequences of /s'/(/z'/) followed by a palatalized segment, only the last of the sequence is affected by depalatalization:

- (69)
- | | | | |
|--------|-----|-----------|---------------|
| wiśń-a | but | wiśen-k-a | 'sour cherry' |
| rażń-a | but | rażen-k-a | 'bath' |

In view of the above, we must conclude that there is a rule in Polish which spreads a palatal constriction of a palatalized consonant.

The constriction model predicts that such processes should occur naturally: on this model, the palatalization spread in Polish is analyzed as the spread of the Palatal/Tongue Body constriction. On the model in which all articulatory properties of a segment are combined under one node, this analysis is not available.

Of course, it is possible to revise the model in (63b) so as to make it capable of handling processes which spread one of multiple articulations: this result can be achieved with indexing devices, and with constraints which disallow the spreading of nodes with different indices. However, since the only role of such devices is to capture the generalizations that are delivered naturally by the constriction model, their stipulatory nature is all too obvious.

Another difference between the constriction model and the representation in (63b) can be seen in the way the two handle processes which spread the Articulator or the Site features

* /e/ is epenthetic, see Górecko (1989).

independently of each other. We have already seen a number of cases which were best analyzed in terms of Site spreading; each time however, there were good reasons for treating such processes as feature-filling, applying to segments that lacked the Site specification.

It would appear that only feature-filling spreading of either Site or Articulator occurs. For instance, I have never seen an example of a rule converting a coronal palatal into a dorsal palatal before any vowel. Or, if the direction of this rule is marked -- its converse: a rule which derives a coronal palatal from a dorsal palatal before any coronal sound (e.g., $c \rightarrow \tilde{c} / __ t, s, \text{etc.}$). I have not seen a rule which would convert $/t/$ into $/s/$ before a coronal, or a rule which would change a coronal palatal into a dental/alveolar before $/t/$, $/s/$, $/n/$, $/l/$ -- segments which are characterized as Anterior.

The constriction model predicts that feature-changing assimilations involving the Site or the Articulator are impossible. This prediction falls out of the assumption that the Constriction Node represents a real gesture which accompanies sound production; by all physical evidence available, such a gesture always involves one articulator and one area of obstruction for every articulation known. To put this in phonological terms -- we know of no phonemic contrast which could be attributed to the fact that in one segment, the active articulator executes a constriction in one area of the vocal tract, but in another, the same articulator participates in two constrictions. On these grounds, I have proposed to represent the Constriction Node canonically as a function of two variables: the Site and the Articulator.

Given that the Constriction Node may not dominate more than one Site and one Articulator, and given the assumption that there are no phonological processes which derive universally impossible representations, the constriction model predicts the absence of phonological processes which spread the Site or the Articulator to replace an existing one.

The model in (63b) cannot deliver the same result: the Place Node of this model may dominate multiple Sites and Articulators, therefore, nothing should prevent the spread of an additional Site or Articulator onto this node. Also, it does not appear to be possible to correct this model with a constraint that would block the spread of a single Site or a single Articulator, because such a constraint would rule out feature-filling applications of such processes as well.

The above considerations constitute sufficient grounds for not regarding the tree in (63b) as a serious candidate for a model of phonological representation. At the same time, the arguments presented in this section provide strong support for the conclusion that an adequate phonological theory must recognize the constituency of a node which represents a single articulation: the Constriction Node. This node must be defined in terms of the Site and the Articulator -- features which map onto the physical parameters of an articulation: the location of the narrowing and the active articulator respectively.

Even with the status of the Constriction Node established, we are still left with at least two questions about the structure of the segmental tree unanswered. The first question concerns the status of the Place Node in the sense of Clements (1985) and Sagey (1986): in those models, the Place Node combines all articulations of a segment; the question that I want to pose is whether such a constituent, distinct from the Root Node, is at all motivated by the phonological facts, or whether, with an independently motivated Constriction Node, the Place Node can be disposed of entirely. Below, I argue that the Place Node is not required.

The second question that remains to be answered is that of the structure within the Constriction Node. So far, I have been assuming that the Site and the Articulator are free agents, independently

suspended from the Constriction Node. However, at least two other arrangements are possible: one, in which the Articulator dominates the Site, and is itself dominated by the Constriction Node, and one in which the order of the Site and the Articulator is reversed. Here, I will argue that the preferred arrangement of the Site and the Articulator under the Constriction Node is one in which the two constituents are dependent on the Constriction Node, but independent of each other.

Let us now take up each of these questions in turn.

4.2 The Status of the Place Node

Sagey (1986) presents evidence for a phonological constituent which combines all articulations of a segment: the Place Node. The evidence consists of cases of nasal assimilations in which the nasal acquires all articulations of an adjacent segment. Sagey discusses various examples of such phenomena in Kpelle, Yoruba, and Dan. Here, we look at the data from Kpelle, where a syllabic nasal assimilates to a consonant on the right, according to the following paradigm:

(70)	N	+	polu	-->	míbolu	'my back'
	N	+	tle	-->	ńdle	'my taboo'
	N	+	kɔɔ	-->	ńgɔɔ	'my foot'
	N	+	kʰɪŋ	-->	ń ^h gʰɪŋ	'myself'

Sagey argues that since the syllabic nasal in Kpelle and the consonant that follows it must be represented on separate X-slots, the only means of accounting for the fact that the nasal and the consonant are articulatorily identical, is to posit an assimilatory process in the language (thus ruling out, for example, a segmental fusion analysis). She points out that to express such a process in terms of a rule spreading the articulators: Labial, Coronal and Dorsal, would be to miss the generalization that all articulatory features are involved in it. Sagey concludes that the most insightful way of analyzing the Kpelle facts, is in terms of a process which spreads a node that combines all articulations of a segment.

In the Clements/Sagey model, an articulator (Labial, Coronal, Dorsal) represents what in the constriction model is represented by the Constriction Node: a single articulation. On that model, it is impossible to refer non-specifically to a single articulation without referring to all articulations of a segment, i.e., without referring to the Place Node. On the constriction model, on the other hand, an instruction to spread the Constriction Node will result in the spreading of all qualifying nodes. Therefore, on this model, it is not necessary to erect a node which combines all articulatory properties of a segment, the Place Node, in order to account for the processes which spread more than one articulation in a segment. Since I know of no other motivation for positing the Place Node, I conclude the argument here.

4.3 The Structure Within the Constriction Node

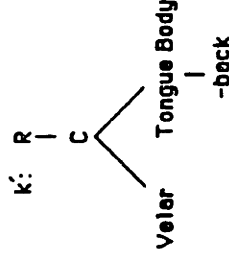
In this section, I present evidence that the Site and the Articulator are not hierarchically dependant on one another, but instead, are sisters under the Constriction Node.

We have already seen arguments for not wanting to represent the Site as embedded in the segmental tree; recall the palatalization of a schwa in Russian and in Margi (Sections 3.3.1 and 3.3.5, and the ablaut facts of Arabic: in all these cases, the preferred analysis was in terms of a rule spreading the Site independently of the Articulator. I take these analyses to imply that phonological processes can access the Site features without involving the Articulator features; this is possible only if the Site does not dominate the Articulator.

Let us now consider a hypothesis that Articulator dominates the Site, and is itself dominated by the Constriction Node. Such an arrangement would be consistent with the phonological facts which never required that the Articulator be manipulated independently of the Site. Later on, we shall consider some analyses which will appeal to the possibility that the Articulator may spread independently of the Site. However, the most persuasive evidence for

segments. I argue in that chapter that fronted velars have the following surface representation:

(71)



Given the representation in (71), the fronting of velars before /i/, /e/, /æ/, etc., cannot be attributed to palatalization -- there is no palatal component in that representation.

An adequate account of velar fronting should be able to explain the mechanism of the process and capture the fact that only velars are fronted before front vowels. Below, I suggest that an analysis in terms of the spreading of the Tongue Body articulator of an adjacent vowel onto the Constriction Node of the velar which lacks the Articulator specification does meet this requirement.

On the assumption that the value of an Articulator is always' underlyingly unspecified in velars, we can derive velar fronting via a process that automatically spreads the articulator of an adjacent segment, as the means of providing the missing part of a representation; probably, not unlike the mechanism responsible for the compensatory lengthening phenomena. Since only the Tongue Body can form a constriction at the velar region, only the dorsal segments (either the non-low vowels or the dorsal palatals) may be the

* Virtually every grammar that lists positional allophones of the basic segments, characterizes velars as front before front and back before back vowels. Occasionally, though, a language may have a velar sound idiosyncratically specified as either + or - back. This might be the case in Standard Polish, where χ appears to be [+back] in the UR, as it has the same [+back] allophone before the front and back vowels.

not embedding the Articulator Node above the Site within the segmental tree, comes from the phenomena in which it is advantageous to treat segments specified for the Site features, but lacking the Articulator. Apparently, such phenomena cannot be treated within a model in which the Articulator is embedded between The Constriction Node and the Site, because, on such a model, it would not be possible to specify the Site of a segment without representing the Articulator of this segment.

Earlier, I have suggested that, taking advantage of the theory of underspecification of Steriade (1987), we may represent velar segments, which are predictably dorsal (no other organ may form a constriction in the velar region) with the Articulator node underlyingly unspecified. Here, I show that there are considerable benefits of such a treatment of velars.

One of the puzzling aspects of the phonological behavior of velar consonants is the readiness with which they assimilate to the frontness of an adjacent vowel. Within the SPE phonology, the fronting of the velars is treated as a result of palatalization. What makes this analysis problematic, is the fact that in most languages, only velars are subject to such a treatment; if the fronting effect is indeed due to the spread of palatal constriction, there is no reason why this should be the case. Even more curious is the frequent absence of "true" palatalization effects in the environments in which velars are fronted, in languages which do have palatalization. For example, in Polish, labials and dentals are palatalized before most suffixes which start with a front vowel, e.g., kot + e --> ko'ce 'cat', zap + e --> 'ape 'paw', etc. But, as mentioned earlier, there are front vowel-initial suffixes which do not trigger palatalization; nevertheless, these suffixes do have the fronting effect on the velars, e.g., kot + em --> kole'm 'cat', xtop + em --> xtop'em 'peasant', but krok + em --> krok'em 'pace', rak + em --> rak'em 'crayfish', etc.

In Chapter 6, I bring up this and other phenomena in which the fronted velars (/k' /, /g' /, etc.), do not pattern with the palatalized

spreaders. This is consistent with the assumption that phonological processes which create ungrammatical representations do not exist.

This analysis goes through only if the articulator value is unspecified in the velar consonants. Otherwise, given the fact that phonologically, velars behave like dorsal segments with no tongue body features, the assimilation of velars to the backness of an adjacent vowel would have to be treated as a phonological process. In order to trigger such a process universally, we would have to posit a universal condition on representation which would make vowels and velar consonants agree in backness. This is just the sort of the condition on representation that does not sound very convincingly when applied universally. If, on the other hand, velars are assumed to have no articulator specification, the only universal condition needed to account for the fronting effect is that all segments be fully specified on surface.

To conclude the above argument, the need for unspecified articulator in a velar segment points up the advantages of a representation in which the Site and the Articulator Nodes are independently dominated by the Constriction Node. If the Articulator dominated the Site, leaving the Articulator value unspecified would entail leaving out the Site value as well. This would make velars completely unspecified segments, open to just about any assimilation, not just an assimilation to the tongue body features.

5. Segment Representation: Vowels

Problems of vowel representation are some of the most complex in phonetics and phonology. First, because of the nature of the organs involved in vowel production, there are difficulties in determining the parameters of vowel articulation. Given the fact that vowels retain their auditory identity throughout varying environments, and from speaker to speaker, at least some aspects of vowel articulation should remain constant. However, in the ongoing debate, there is little agreement as to which aspects of vowel pronunciation are stable enough to qualify as articulatory parameters. According to some, vowels should be characterized in terms of the tongue body position; others appeal to the constriction location as the articulatory parameter (see Chapter 1 for discussion).

For the theory of phonological representation which posits features based on articulatory properties of sounds, the problem of articulatory accuracy is also a matter of concern.

Another major problem for the theory of vowel representation, not present on the same scale in the phonology of consonants, comes from the variation in the behavior of seemingly identical segments. It is not uncommon that seemingly identical vowels do not behave alike w.r.t. seemingly identical phonological processes. For example, in some languages, the vowel /a/ is neutral w.r.t. a height harmony, but in others, it actively participates in an identical process. Or, in one language the vowel /i/ patterns with palatals (č, š, ç, etc.), but in others, it patterns with the anterior consonants (t, s, ts, etc.).

In the early years of generative phonology, when rules were expected to carry the main burden of crosslinguistic variation among phonological phenomena, idiosyncrasies of the sort pointed out above were of lesser concern. However, recent developments in phonology have shown that many constraints on phonological rules are best derived from the structure inherent in the representations to which

the rules apply. It is reasonable to hypothesize that the same line of research can be profitable in solving the problem described above.

Finally, an outstanding problem for a theory of vowel representation are vowel/consonant interaction phenomena. In an attempt to solve this problem, Chomsky and Halle (1968) have proposed to characterize consonants which do interact with vowels in terms of the tongue body features. For example, SPE treats /ɛ/-like sounds as [+high, -back], velars as [+high, +back], uvulars as [-high, +back], pharyngeals as [+low], etc. However, it has been shown (see the discussion in chapter 3) that this proposal is descriptively incorrect (at least in the case of segments such as uvulars), and phonologically inadequate. For example, there are no known cases of /ɛ/ blocking or triggering the height or the backness harmony, /k/ is as a rule transparent to all dorsal harmonies, and pharyngeals are not even articulated with the tongue body. Given that the SPE or SPE-like proposals (such as Sagey's (1986)) cannot explain vowel/consonant interaction, these phenomena continue to be a problem for the present day phonological theory.

In this chapter, I address the problems pointed out above in some detail. Since I propose to characterize vowels in terms of both the active articulator, and the constriction location, I argue that both theories of vowel articulation mentioned above are essentially correct, and I try to deal with the criticisms against them. For obvious reasons, I devote a great deal more time defending the view that vowels can and should be represented in terms of the constriction location. After all, the view that articulators are important in the representation of vowels is more or less standard, and needs little support.

I also suggest ways of solving some of the problems of variation in the phonological behavior of vowels by appealing to the differences in the representation of seemingly identical segments. It turns out that the problem of articulatory accuracy, and the problem of variation are often surface manifestations of the same phenomenon: often the cases in which an /i/-like vowel is observed

to have a constriction in the anterior instead of the palatal region (contrary to the predictions of the theory which characterizes vowels in terms of the constriction location), turn out to be the same as the cases in which an /i/-like vowel behaves phonologically like an anterior segment. This is possible to observe in languages in which the phonological properties of an articulatorily "misbehaving" vowel are reflected in the phonological processes.

Finally, the constriction model offers a solution to the problem of vowel/consonant interaction phenomena: on this model, all articulatory features are equally accessible to vowels and consonants. This has never been the case in any of the earlier proposals -- neither the IPA nor the SPE feature systems have allowed to characterize vowels in terms of point of articulation/constriction location features.

This chapter is organized as follows: sections 5.1, 5.2, and 5.3 are devoted to Site features in vowels -- the phonological arguments in section 5.2 are a review of the arguments for the constituency of Site features, presented in chapter 3. Sections 5.1 and 5.3 deal with the articulatory aspect of Site features; in 5.1, I review the arguments from phonetics for the view that treatment of vowels in terms of the constriction location is articulatorily sound. In 5.3 I present arguments that the Site features I posit coincide with the regions of articulatory stability in vowels. I also defend the treatment of vowels in terms of the constriction location from the criticism that it articulatorily unreliable.

I then discuss the status of the Articulator in vowels, and present evidence that the Articulator features are required in vowel representation, in addition to the rich system of Site features. Next, I argue for the Constriction Node in vowels on the basis of phonological processes which can be understood only in terms of Constriction assimilation. Finally, various issues concerning individual segments are discussed.

5.1 The Articulatory Basis of Site Features in Vowels: Part 1

One of the main claims of this thesis is that the phonological representation of a speech sound includes features which correspond to the location of the constriction(s) associated with sound production. While this claim is not new in phonology, it is uncontroversial only as far as the treatment of consonants is concerned: the constriction location plays a role in the IPA classification of consonants (in terms of features [labial], [labiodental], [dental], [alveolar], [palato-alveolar], [palatal], [velar], [uvular], [pharyngeal], and [laryngeal]), and, to a lesser extent, in the SPE framework, which must appeal to a feature like [anterior], in order to account for the phonemic contrasts among the coronals.

The view that articulatory properties of vowels can be expressed in terms of the constriction location, originally due to the Sanskrit grammarians (cf. Varma (1929), Allen (1953)), enjoyed a great deal of popularity in the times preceding the introduction of the tongue arch model. Through cultural contact, this view spread to China, Japan, Arabia, and to Europe, where it is reflected in the works of John Hart (1569) (discussed in Danielsson (1955)), Jacob Madsen af Aarhus (1589) (discussed in Møller and Skautrup (1930)), Hellweg (1781), and Bell (1849)*, among others.

In 1867, Alexander Bell introduced a new way of representing vowels; he observed that the tongue position varied for different vowels, and he proposed to account for this fact in a model in which articulatory properties of vowels were expressed in terms of the position of the highest point of the tongue. Bell's model gave rise to the high-low, front-back feature system which forms the basis of virtually all vowel classifications currently available. Following Wood (1982), I will refer to this system as "the tongue arch model".

For almost a century, the tongue arch model overshadowed all other methods of characterizing vowel articulation, including, the ancient method based on the constriction location. Its success has not been diminished by the X-ray findings of Meyer (1910), Russell

* These references are quoted after Wood (1982).

(1928), etc., which revealed a discrepancy between the model and the articulatory reality. (The criticisms raised by the researchers will be discussed in more detail in section 5.3.) Nevertheless, dissatisfaction with the tongue arch model has led some researchers to look for alternative means of characterizing vowel articulation.

Of particular interest to the present discussion is the proposal by Sidney Wood (1979, 1982), who confirms the results of Meyer, Russell, etc., in a large scale crosslinguistic study of vowel articulation. Wood considers the discrepancy between the tongue arch model and the phonetic reality to be serious enough to render the model useless. Instead, he proposes a return to the Sanskrit grammarians' tradition of characterizing vowel articulation in terms of the constriction location. He recognizes four (rather than three) basic constriction locations for vowels: palatal, velar, upper pharyngeal and lower pharyngeal.

With the exception of the feature [tense], Wood rejects the tongue body features [high], [low], [back]. In his model, vowels are characterized in terms of the following binary features: [palatal], where [+palatal] are /i/, /ɪ/, /e/, /ɛ/, /u/, /ʊ/, /ɔ/, /ɒ/, where [+velar] are /u/, /ɔ/, /o/, /ɔ/, [pharyngeal], where [+pharyngeal] are /o/, /ɔ/, /a/, [open], where [+open] are /e/, /ɛ/, /ɔ/, /ɒ/, /a/, and [tense], with the usual coverage. Notice that in Wood's terms, the feature [open] takes over the function of the feature [high], thus making the model capable of capturing the height phenomena.

Wood defends this model on the basis of X-ray evidence which, he argues, reveals similar constriction locations for similar vowels, both for the tokens from the same language, and crosslinguistically. He also compares the area functions of similar vowels from various languages, and derives the same conclusion. The only crosslinguistic variation that he observes, is in the constriction location of the vowel /ɪ/, which tends to be "more anterior" (Wood (1979) p. 34) in languages which have more than two high vowels, and in the vowel /u/, which may be near-palatal, velar or uvular (I will return to the

topic of crosslinguistic variation in the constriction location of vowels later on, in section 5.3.)

Finally, Wood studies the EMG records of the activity of the extrinsic tongue muscles, which are traditionally considered to be responsible for the position of the tongue during vowel production. On the basis of these records, and anatomical descriptions, he concludes that the four places of constriction: palatal, palatal-velar, velar-pharyngeal, and pharyngeal are ideally correlated with the movements these muscles can execute.

While the model of segment representation developed in this thesis differs in many respects from Wood's model, some of his results are directly relevant to the proposal I am making. Wood presents a considerable body of evidence for the claim that vowels can be reliably characterized in terms of the constriction location.

The view that the place of constriction can be a parameter of vowel articulation has also been expressed in the context of research on acoustic-articulatory correspondences (Stevens and House (1955), Fant (1960), etc.). As pointed out by Fant (1960), the articulatory parameters of the tongue arch model are somewhat awkward to use in computations relating the articulatory and the acoustic data.

On the basis of the results in Stevens and House (1955), Fant (1960), and Wood (1979, 1982), it is possible to conclude that since similar quality vowels are associated with similar constriction locations, phonological features based on the constriction location of a vowel are a priori possible. The question that remains to be answered is whether the constriction regions for particular vowels correspond to features which a phonologist might want to posit on the basis of the phonological behavior of the vowels. Since this question can be answered properly only after the inventory of Site features for vowels is established, I return to it following the section which reviews the arguments for representing vowels in terms of constriction location.

5.2 Phonological Arguments for Site Features in Vowels

I have presented the main body of evidence for the phonological constituency of the Site features in vowels in chapter 4, when I argued for the phonological status of these features in general. In a large number of cases, the phenomena in which the Site features were activated, involved consonants as well as vowels. Therefore, the present section should be viewed largely as a review of the arguments presented in chapter 4, with the discussion focused on vowels to a greater extent.

5.2.1 Labial Site in Vowels

Vowels represented with the Labial Site include u, ɔ, o, ɔ, ʊ, and ɐ. The evidence for the phonologically active Labial Site in vowels comes from labial dissimilation phenomena in Venda and in Zulu. In Venda, discussed earlier in 3.1.1, dissimilation effect is observed with bilabial consonants (ɸ, β, m, p^h, p, b), when they are followed by the passive suffix /-wa/. The following alternations are reported by Doke (1954): fricatives become velarized before /-wa/; stops do not undergo any change, but instead, the round glide that follows them turns into a velar fricative. With the nasal /m/ both patterns of behavior occur. Before the /-iwa/ alternant, no dissimilation is observed. The relevant data are repeated below:

(72)(a)	βɔɸ + wa --> βoxwa/βoɸiwa	'be tied'
	diβ + wa --> diɣwa/diβiwa	'be known'
	nɔp + wa --> nɔpxe/nɔpiwa	'be switched'
	k'ɔp ^h + wa --> k'ɔp ^h xɛ k'ɔp ^h iwa	'be broken off'
	beb + wa --> bebɣe/bebiwa	'be begotten'
	lum + wa --> lumwɛ/lumɣɛ	'be bitten'
(b)	fun + wa --> funwa/funɣiwa	'be loved'
	rend + wa --> rendwa/rendiwa	'be praised'

Doke (1954) reports that only bilabials participate in the dissimilation process. Since Venda does have labiodental fricatives

in its segment inventory, the data in (72a) cannot be analyzed in terms of dissimilation at the Articulator tier. Therefore, the rule responsible for these data must be stated in terms of the Labial Site.

While the passive suffix in Bantu is conventionally written /-wa/ in the linguistic literature, it is more appropriate to analyze it as a sequence of vowels /u/ and /a/, and, following Guerssel (1988) and Levin (1985), who treat /u/ and /w/ as two syllabification variants of the same segment, derive the surface /-wa/ from a process that glides the high vowel when it is followed by another vowel. Support for such an analysis comes from the fact that there are no sequences of /u/ followed by a vowel in Venda.

Given the above analysis, it follows that the vowel /u/ must be represented with the Labial Site in order to trigger the dissimilatory process illustrated in Venda.

Let us now consider briefly the dissimilatory process affecting bilabials in Zulu (discussed more extensively in 3.1.2). In Zulu, dissimilation of bilabials occurs not only before the passive suffix, but also in two other environments when a bilabial is before a stem-final round vowel, followed by the locative suffix /-ini/. Dissimilation affects bilabials only, and the result is a palatal segment. The rounded vowel turns into a glide. This is illustrated below (only a fraction of the data from 3.1.2 is repeated here):

- (73)(a) -be:b + we --> -be:dʒwe 'be trapped'
 -tʊ:pʰ + we --> -tʊ:šwe 'be teased'
 -tʰu:m + we --> -tʰu:nwe 'be sent'
- (b) -don + we --> -donwa 'be seen'
 -don + we --> -donwa 'be praised'
 -tʰand + we --> -tʰandwa 'be loved'
- (74)(a) e + tsitʃ:ʃɔ + ini --> esitʃɔʃ:ni 'friend'
 e + umlɔ:ms + ini --> emlɔne:ni 'mouth'

- (b) e + t:seŋo + ini --> esenwɛni 'gateway'
 e + t:zulu + ini --> ezulwini 'sky'
- (c) e + t:fu + ini --> ef:ini/efwini 'cloud'
 e + t:mbvu + ini --> embvini/embvwtini 'sheep'
- (d) e + t:mpɪ + ini --> empini 'army'
 e + t:ntaɓa + ini --> entaɓeni 'hill'

The above data point to a dissimilatory process which affects bilabial consonants followed by round vowels (for detailed analysis see 3.1.2). In order to exclude the labiodentals from undergoing the process (cf. (74c)), it is necessary to limit the scope of the dissimilation rule to segments characterized by the Labial Site. This is possible only if round vowels are represented with this feature.

5.2.2 Palatal Site in Vowels

The inventory of vowels which I propose to represent with the phonological feature Palatal Site, consists of /i/, /y/, /e/, and /ɛ/. Evidence for the Palatal Site in these vowels comes from the facts of schwa assimilation in Russian (3.3.1), Arumanian (3.3.4) and in Margi (3.3.5), from vowel palatalization in Bulgarian (3.3.2) and in Polish (3.3.3), and, most importantly, from the palatalization phenomena, to be discussed in chapter 6. I will briefly review here some of these cases.

In Russian, we have seen a phenomenon in which a phonemically unstressed /a/ and /o/ turn into a schwa, which, if followed by a stressed vowel, assimilates to the palatal quality of the preceding consonant. The result of the assimilation is /ɤ/, as shown in (75a). Otherwise, a schwa in the pretonic position surfaces as /ʌ/. This is shown in (75b). (stressed vowel is in bold type):

- (75)(a) juʒk /jaʒk/ 'tongue'
 čist /čest/ 'watch'

* The /ɤ/ alternation will be explained below.

	ju:ə	/je:ə/	'hedgehog'	χə:ə	'arrow'
	n'ɪstə	/n'ostə/	'was taking', fem.		
(b)	same	/səmə/	'self', fem.	čú	'speck'
	gʲəzə	/gʲəzə/	'eyes'	šú	'spin'
	xəd'ɪt'	/xod'ɪt'/	'to go'	čù	'tear'
	nəgə	/nogə/	'leg'	nʲú	'burn'

Since in Russian, the schwa can assimilate to any consonant with the palatal constriction location (coronal or dorsal), and only to such consonants, and since the result of the assimilation is /ɪ/, it follows that /ɪ/ must be represented with the palatal constriction location (Palatal Site) as well.

In Arumanian, the result of a process which assimilates schwa to a palatal consonant (either coronal or dorsal) is /e/. This is shown below:

(76)(a)	purt	→ e	→>	purtə	'carried'
	kr	→ e	→>	lukre	'worked'
	be	→ e	→>	beše	'kissed'
	te	→ e	→>	te'e	'cut'

Here again the Articulator active in the constriction of a consonant to which the schwa assimilates makes no difference in the quality of the assimilated vowel. This indicates that the spreading feature must be the Palatal Site. It follows then that the phonological representation of /e/ must involve a Palatal Site.

In Margi, a word-final schwa turns to /ɪ/ only when preceded by a palatal consonant (coronal or dorsal), or a palatal glide. This is shown below:

(77)	/ə/ in word-final position:	/ə/ in phrase-final position:
sə	sù	'thing'
bəə	bəù	'chew'

The argument made for the Russian and Arumanian data holds here as well: since the assimilatory feature may only be the Palatal Site of the trigger consonant, it follows that the resulting segment, /ɪ/, must also be represented with the Palatal Site.

I conclude here the arguments for the Palatal Site in the representation of /ɪ/, /ɛ/, /e/, and /ɛ/. The only vowel for which I posited the Palatal Site, but did not present phonological evidence, is /e/. However, since this vowel is a lax counterpart of /e/, it is possible to extend the conclusions about the constriction features of /e/ to the representation of /ɛ/.

5.2.3 Velar Site in Vowels

The inventory of vowels characterized with the feature Velar Site includes /u/, /o/, /ɔ/, and /ɜ/. Phonological evidence presented in support of the feature Velar Site in section 3.4 -- velar dissimilation in Polish, and vowel hardening in Kinyarwanda, can also be quoted in support of the claim that this feature is present in the representation of vowels /u/, /o/, /ɔ/, and /ɜ/. I review both cases here briefly.

In Polish, a stem-final velar consonant turns into a coronal palatal (either /ç/, /dʒ/, or /ʃ/), when followed by a suffix that starts with either a velar consonant or with /u/. The relevant data are repeated below:

(78)(a)	pij-ek	pij-oč-k-a	'drukerd'
	nog-a	nuš-k-a	'leg'
	ux-o	uš-k-o	'eer'

nog-a	nož-uš-a	'leg'
vilk	vilē-uš	'wolf'
rēk-a	rōč-un'-a	'hand'
nog-a	nož-un'-a	'leg'
(b)		
kot	koit-k-a	'cat'
rur-a	rur-k-a	'pipe'
tat-a	tat-uš	'dad'
rab-ov-a-č	rab-uš	'thief'
mem-a	mem-un'-a	'mom'
tsur-a	tsur-un'-a	'daughter'

In section 3.4.1, I have argued that the phenomenon illustrated above is best analyzed as a case of dissimilation triggered by the OCP applying at the Velar Site tier. Such an analysis is possible only if the vowel /u/ is represented with the Velar Site.

In Kinyarwanda, a non-low vowel fuses with the preceding consonant when followed by another vowel, according to the following paradigm: a back rounded vowel adds a labiovelar component (k^w) to the consonant; a front vowel turns into a palatal/dorsal component. This is illustrated below:

(79)(a)	lu + a:ngə --> t ^{kw} a:ngə	'we hate'
	ku + dód + u + ə --> kúdoð ^{mw} a	'to be sewed'
	ku + βon + u + ə --> kuβon ^{mw} a	'to be seen'
(b)		
	ku + se + ə --> kuš ^ə a	'to grind'
	ku + rɪ + ə --> kur ^ə a	'to eat'
	ɪmɪ + u:ge --> ɪm ^ɥ u:ga	'professions'

The facts of Kinyarwanda support the claim that /u/ and /o/ must be represented with the Velar Site, because only under this assumption can the difference in the behavior of front and back vowels be explained. In a theory in which vowels are characterized solely in terms of the active articulator, they are distinguished only

by the tongue body features. /k/, on the other hand, bears no tongue body features (see the discussion in 3.4.2), and so, it ought to pattern with a vowel such as /e/ in the same way it patterns with /u/.

5.2.4 Pharyngeal Site in Vowels

The inventory of vowels which are characterized with the feature Pharyngeal Site includes /o/, /ɔ/, /e/, /ɛ/, and all /a/-like vowels. Evidence for the Pharyngeal Site in /o/ and /e/ comes from the vowel lowering facts of Greenlandic Eskimo, discussed in 3.5.4. In Greenlandic, high vowels /i/ and /u/ are lowered to /e/ and /o/ respectively when followed by uvulars /x/ or /r/. Data illustrating this phenomenon are repeated below:

(80)	seameq	'glecier'	neerlooq	'goose'
	iseaeq	'ankle'	iperaeq	'harpoon strap'
	qesaleq	'bear'	nanooq	'bear'

Given that uvulars may not be characterized as [-high] (cf. McCarthy (1989), and the discussion in 3.5.4), vowel lowering in Greenlandic cannot be analyzed in terms of height assimilation. Therefore, the only way to treat this phenomenon, is to attribute it to the spread of a feature which corresponds to the constriction location of the trigger*. Uvular consonants, being complex segments (cf. McCarthy (1989)), have two constrictions: one velar and one pharyngeal. Clearly, the velar constriction does not spread, as can be seen from the fact that /i/ turns into /e/ -- a non-velar segment. Therefore, it must be the case that the pharyngeal constriction of a uvular

* Actually, it is possible to propose an analysis of vowel lowering in Greenlandic contained entirely within the articulator theory of phonological representation: on the assumption that uvulars are represented with both dorsal and tongue root articulators, the lowering effect the uvulars have on the adjacent vowels can be attributed to the spread of the tongue root (of course, vowels /e/ and /o/ would have to be represented as complex segments involving the tongue root as well). However, the success of such an analysis is short lived, since, as pointed out by McCarthy, the tongue root is not an active articulator in all pharyngeal sounds. For example, the laryngeals may not be included in a natural class with, say, pharyngeals, on the basis of an active articulator, but they do form a natural class with these segments nevertheless.

spreads in Icelandic. Such an analysis entails that /e/ and /o/ contain a pharyngeal component in their representation.

Evidence for the Pharyngeal Site in /a/ comes from the processes in Tiberian Hebrew, which turn the schwa to /a/ before/after a guttural consonant (discussed in more detail in 3.5.1). The relevant data are repeated below:

(81)(a)	/meik/ --> melek	'king'
	/ʔereʃ/ --> ʔareʃ	
	/qodš/ --> qodeš	
(b)	/baht/ --> béhet	'costly stone'
	/beʕ/ --> béʕel	'master'
	/bath/ --> bétah	'name of city'
	/bels/ --> béles	'swallowing'

In 3.5.1, I have argued for an analysis of the Tiberian Hebrew facts which attributes the e --> a change to the spread of the Pharyngeal Site of a guttural onto the Constriction Node of the reduced vowel. It follows from this analysis that /a/ must bear the phonological specification for the feature Pharyngeal Site.

This concludes the review of arguments for representing vowels with a phonological feature: Site. In the next section, I address the question whether the Site features which I posit (Labial, Palatal, Velar and Pharyngeal) have solid basis in the articulatory reality.

5.3 The Articulatory Basis of Site Features in Vowels: Part 2

5.3.1 The Articulatory Basis of the Labial Site

The feature Labial Site is posited here for vowels /u/, /o/, /u̠/, /ö/, /ɔ/, /ɔ̠/, /ɔ̡/, and /a/. All rounded vowels involve labial gesture in which both lips participate. While there are reports of certain amount of crosslinguistic variation in the lip shapes for these vowels (cf. Linker (1982)), I know of no example of variation

in their constriction location. Therefore, it is possible to conclude that Labial Site is articulatorily well defined.

5.3.2 The Articulatory Basis of Palatal Site

Vowels which I propose to characterize with the feature Palatal Site, are /i/, /ɪ/, /e/, and /ɛ/. According to Wood, these are also the vowels which are articulated with a constriction in the palatal region (based on radiographic evidence). However, as Wood points out, not all cases of /i/, /ɪ/, etc., involve palatal constriction. After comparing the area functions of /i/ uttered by a speaker of Southern British English, American English, and Egyptian Arabic, he concludes that the constriction for the vowel uttered by the Egyptian Arabic speaker is much more anterior than the constriction produced by the Southern British English or American English speakers (about 8 mm closer to central incisors than the constriction of the British English speaker's /i/, and about 13 mm closer than the vowel of the American English speaker). Wood mentions that this shift in the constriction location of /i/ is particularly common in languages which have more than two high vowels (/t/ or /ɪ/, in addition to /i/ and /u/) in their inventories (although this is not the case in Egyptian Arabic). He quotes Fant (1965) for similar observations about /i/ in Scandinavian languages and in Russian, compared to its American English counterpart. Fant characterizes the Russian and Scandinavian /i/ as "prepalatal", and the American English /i/ as "mid-palatal". Fischer-Jørgensen (1985) also mentions vowels which have the maximum constriction at the alveolar ridge, and quotes Straka (1978), who calls French /i/ an alveolopalatal, or simply an alveolar.

These facts seem to indicate that, contrary to the assumptions on which the constriction model is based, namely, that the constriction location of a vowel is stable, the constriction location of a vowel may vary across more than one articulatory region. Given Wood's (1979) and Fant's (1965) descriptions, some languages appear to have the constriction for /i/ in the dental/alveolar region of the

vocal tract. This region forms the basis of the feature Anterior Site, well motivated by the phonology of the dental/alveolar consonants.

The question that naturally poses itself at this point, is whether the /i/ of Scandinavian languages, Egyptian /r/abic, or Russian is still to be treated as a palatal segment. If the answer to this question is yes, then the concept of articulatorily defined Site features should either be abandoned, or modified so as to allow different articulatory definitions for consonantal and vocalic Sites. Of course, such a proposal weakens the concept of the Site features considerably.

However, this concept, and the constriction model which depends on it, would not need to be compromised, if it could be shown that the vowel /i/ must be represented with the Anterior Site in languages in which it is articulated with a constriction in the anterior region of the mouth.

Apparently, there exist phonological phenomena whose interpretation requires that the vowels /i/ and /e/ be treated as Anterior. An example of one is a velarization process affecting /i/, /e/, and /u/ in Standard Thai, mentioned briefly in 3.2.1. I now consider this phenomenon in some detail.

5.3.2.1 Velarization in Standard Thai

In his characterization of consonants of Standard Thai (segment inventory after Ruhlen (1975): i, t, u, e, o, ɔ, s, ɔ, a, some series with length; p, pʰ, b, m, f, t, tʰ, d, s, n, l, [r], ɕ, ɕʰ, k, kʰ, g, ŋ, ʔ, h), Harris (1972) reports that /i/, /e/, and /u/ become velarized syllable-initially, before close front vowels. Velarization is perceived as a back unrounded off-glide. The following are examples that illustrate this phenomenon (after Harris (1976)):

(82)(a)	rɪ:	'a bolɪ'	(b)	rá:	'sky'
	sɔ:	'four'		sǔaɪ	'pretty'
	tʰi:	'to hit'		ta:	'eye'

As pointed out in 3.2.1, the only way to characterize {f, s, t} as an articulatorily natural class, is to appeal to the fact that these segments are produced with a constriction in the dental/alveolar region. Within the constriction model, this region forms the basis of the feature Anterior Site.

Under the assumption that vowels /i/ and /e/ in Thai share this feature with {f, s, t}, velarization of anterior consonants can be explained as a dissimilation process, triggered by the OCP applying on the Anterior Site tier.

While there are no radiographic data on the articulation of /i/ and /e/ in Thai, it is possible to speculate about the articulatory characteristics of these vowels on the basis of the acoustic data, which, fortunately, are available.

Wood (1979) reports that articulatory differences between the /i/ of British English and that of Egyptian Arabic are reflected in the acoustic properties of these vowels: "The consequence of the less anterior mid-palatal constriction is a wider pre-palatal part and narrower post-palatal part, which will both yield a lower F₃". Conversely, the more anterior vowel has a "maximally high F₃" (Wood (1979, p. 34)).

At first glance, the acoustic data on Thai (Abramson (1962)) do not suggest that the vowel /i/ has an anterior constriction. The third formant of this vowel ranges between 2600 and 3200 cps, with the mean average of 2910 cps, based on 15 measurements of vowels uttered by two (male) speakers. By comparison, the third formant of /i/ uttered by the male speakers of American English averages between 2775 cps (Lehiste (1964)) and 3010 cps (Peterson and Barney (1952)). Given that the American English /i/ is articulatorily characterized as mid-palatal (cf. the comments above), then, if the third formant is a true indicator of the constriction location in high vowels, it would appear that /i/ in Thai should have roughly the constriction location of the American English /i/.

However, the F_3 of the Siamese /i/ is interpreted differently, when considered together with other formants. The F_1 of this vowel ranges between 260 and 360 cps, averaging at about 322 cps. Compared to $F_1 = 270$ of the American English /i/ (Peterson and Barney (1952)), the F_1 of the Siamese /i/ implies a phonetically somewhat lower vowel, for which the F_3 average of 2910 cps does indicate a fairly anterior constriction*. It is useful to compare here the formant structure of the Siamese /i/ with the formants of the American English /i/, a front lax vowel, which, as a consequence of laxness, has a lower tongue body position than /i/, even though it is phonologically "high". This mid-palatal vowel has F_1 of about 390, and $F_3 = 2550$ cps (Peterson and Barney (1952)). What this shows is that lowering of F_1 will result in lowering of F_3 without the shift in the constriction location.

While the ultimate evidence for the anteriority of /i/ in Siamese should come from the articulatory data, either X-rays or palatograms, the acoustic properties of this vowel can be interpreted to suggest the constriction location more anterior than in an average /i/.

What can be concluded on the basis of the Siamese data, is that the shift in the constriction location of a vowel is not phonologically neutral. Siamese /i/, which can be hypothesized to have an anterior constriction location on the basis of its acoustic properties, patterns in a phonological process like a segment represented with a phonological feature Anterior Site.

5.3.2.2 Anterior Vowels in Other Languages

* it is not the case that the higher F_1 of the Siamese /i/ could be attributed to a possible smaller size of the vocal tract of the subjects in the experiment if this were the case, all formants, for all vowels should be raised, just as they are in the speech of women and even more so, children. For example, the formant structure for the American English /a/, uttered by an adult male is $F_1 = 730$, $F_2 = 1050$, $F_3 = 2440$ cps. The same vowel uttered by a woman has the $F_1 = 650$, $F_2 = 1220$, and $F_3 = 2010$ cps; by a child -- $F_1 = 1030$, $F_2 = 1370$, $F_3 = 3170$ cps (Peterson and Barney (1952)). By comparison, the Siamese /a/ uttered by a male speaker has $F_1 = 670$, $F_2 = 1400$, and $F_3 = 2350$.

Before leaving the present topic, let us consider some of the consequences of the proposal made above. If all vowels articulated in the anterior region of the mouth are to be treated as phonologically Anterior, then the /i/ of Russian, with a very forward constriction (cf. the tracing in Fant (1980), p. 107) and the high F_3 (3200 cps; Fant, *same*, p. 109) to further confirm the validity of the X-ray reading, ought to behave phonologically like an Anterior segment. However, the facts of Russian do not bear out this prediction. If anything, the Russian /i/ acts like a palatal segment, in that it triggers a palatalization rule which converts velars into coronal palatals: muk-a/muč-i-i' 'torture/to torture'.

One way out of the difficulty posed by the palatalization acts is to attribute the palatalization effect not to /i/, but to a diacritic with which suffixes that trigger the rule would be represented. Such a diacritic (or a floating palatal segment -- at this point the difference is not important) is independently needed in order to account for palatalizing properties of suffixes like /-n/ (e.g., kn'ig-a/kn'iz-n-a) 'book'), which are not overtly represented with segments that are likely to have palatalizing properties. Also, not all suffixes that begin with /i/ trigger palatalization, e.g., kn'ig-a/kn'ig-i 'book', which shows that palatalization is not a true phonological rule of Russian, but a highly lexicalized phenomenon instead.

Another way of accounting for the behavior of the Russian /i/ is to appeal to the fact that of the three high vowels in the language, only /i/ and /u/ are underlying segments, /y/ being derived from /i/ by the process mentioned earlier in 3.3.1. It is conceivable that the Anteriority of /i/ is a derived effect, one that follows the rule deriving /y/.

If you recall Wood's generalization mentioned earlier, the "anterior" vowels are most likely to occur in languages with more than two high vowels. This suggests that the "anteriority" of a vowel is a product of those processes which regulate the articulatory and perceptual distances between sounds, in accordance with the

"dispersion" theory initiated by Jakobson (1941), Martinet (1955), and recently further developed by Lijencrants and Lindtjorn (1972). Since in Russian, the "third" high vowel (/ɨ/) is derived, it is not unreasonable to assume that the anteriority of /ɨ/ is a derived phenomenon as well, and that it is ordered after the rule which creates /ɨ/.

5.3.2.3 Second Velar Palatalization in Polish

The above analysis can be profitably extended to Polish, which, as far as the vowel system is concerned, resembles the situation found in Russian in a number of ways. Polish too has three high vowels: /ɨ/, /u/, and /ɨ/. Anteriority, the Polish /ɨ/ appears to be very anterior, as shown on the tracing in Wierzchowska (1965), p. 83. Unfortunately, the acoustic data are available only for the first and second formants of this vowel.

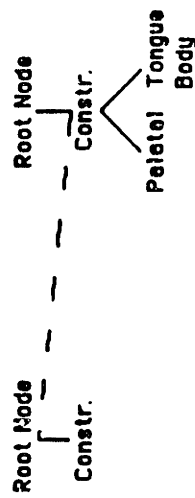
An interesting fact of Polish is that in some cases (mainly in derivational suffixes), /ɨ/ acts like a palatal vowel, and palatalizes the preceding /k/ to /tʃ/, e.g., /hak/ 'hook', /hač-+k/ 'little hook', but in others (mainly in inflections), it triggers "anteriorization" of the preceding velar (in the Slavic linguistic tradition, this phenomenon is referred to as "second velar palatalization"), e.g., /jak/ 'how', /jats-+/ 'which', /vroq-a/vrodz-+/ 'hostile', etc. The anteriorization cannot be dismissed easily as a morphological idiosyncrasy, because the same suffixes that trigger this behavior in velars, cause the labials and the dentals to become "palatalized" (here, in the sense of acquiring a vowel-like articulation), for example /kolorov-a/kolorov'-i/ 'colourful', /červon-a /červon'-i/ 'red'. In this respect, they pattern like suffixes which trigger k → č rule, for example: /ok-o/ 'eye', /z-oč-+t-č/ 'to notice', and /prav-o/ 'law', /prav'-i-č/ 'to preach', /ran-a/ 'wound', /ran'-i-č/ 'to wound'.

An assumption that a vowel may change its Site specification as a reflex of the dispersion phenomena, could possibly explain the

* In Polish /ɨ/ never appears after /tʃ/, /dzʃ/, /ʃ/, /zʃ/, /tsʃ/, and /dzʃ/ it is always converted to /ɨ/ after these consonants.

dual nature of the Polish /ɨ/. As argued by Gussman (1988) and Czaykowska-Higgins (1988), /ɨ/ in Polish must also be derived from /ɨ/. Suppose that prior to the arrival of /ɨ/ (very likely, an unrounded velar), the vowel /ɨ/ is represented with the Palatal Site. The process which spreads the constriction of this vowel onto a consonant can be represented as follows:

(83) Palatalization:



This rule results in velars turning into coronal palatals, and non-velars acquiring the secondary /ɨ/-like constriction. I analyze the effect this rule has on velar consonants as a result of a feature readjustment process: complex segments which mention an Articulator or a Site more than once are not attested, and in all likelihood, are not possible. A palatalized velar would be an example of such a segment, since it would have the Tongue Body involved in the velar constriction and in the palatal constriction as well. In Polish, the velar constriction is deleted and the palatal constriction surfaces with the default articulator -- the Tongue Blade.

Next, suppose that the affixation of inflectional morphemes takes place in a separate component of the grammar (cf. Czaykowska-Higgins (1987) for an argument to this effect), at the point when /ɨ/ is already present in the inventory, and /ɨ/ is

* Given the explanation that palatalized velars may not surface because they are not possible segments, a question may naturally arise as to why should such segments be derived in the first place, particularly, in view of the assumption made in this thesis, that impossible segments are not derived by phonological rules. To answer this question, I would like to appeal to the idea introduced earlier, namely, that the Articulator value is not specified in velars in the Underlying Representation. Therefore, the spreading of a constriction that involves the dorsal articulator should not be blocked by at such a stage.

reanalyzed as a segment with an Anterior Site (for convenience, I will use /ɔ̟/ as a graphic symbol for such a vowel). The effect that /ɔ̟/ has on the preceding consonants no longer needs to be attributed to a separate process (not very easy to explain under any assumption). The anteriorization of velars is derived in the same way that palatalization has been derived a moment earlier: the process which spreads the entire constriction of /ɔ̟/ takes place. It has exactly the same format as the palatalization rule in (12), except that the vowel is now represented with the Anterior Site. First, the non-velar consonants emerge from this process with an /ɔ̟/-like constriction (most likely, all /l/-like constrictions are realized as /ɔ̟/-like at this point). The /ɔ̟/-like constriction spreads onto velars as well. However, since the segment which combines the Velar/Tongue Body and the Anterior/Tongue Body constrictions is not a possible sound, its velar constriction is deleted, and it surfaces as a segment with the Anterior constriction only, and the Tongue Blade as the default articulator -- either /tʃ/ or /dʒ/, depending on the input⁵.

This concludes the discussion of articulatory variation among /l/ like vowels. Let us recapitulate the main points briefly: while considerable variation in the articulation of /l/ has been observed, there are good reasons for treating the "displaced" vowels precisely in terms of the constriction location suggested by their articulation. This result further supports the position that phonological features based on the constriction location of speech sounds, in particular, the features Anterior Site and Palatal Site, are phonetically sound.

5.3.3 Articulatory Basis of the Velar Site in Vowels

Vowels which I propose to represent with the Velar Site are the following: /u/, /o/, /ɑ/ and /ɔ/. To some extent, this is similar to the proposal by Wood (1979, 1982), who, too, characterizes these

⁵ In this process, /x/ does not pattern with /tʃ/ and /dʒ/, but palatalizes to /ʃ/. Instead, this is not the only phonological peculiarity displayed by this sound in Polish. Perhaps the behavior of this sound will be better understood once its phonological status is assessed correctly.

vowels as [-velar]. The main difference between Wood's proposal and mine is that I treat /u/ and /o/ as just velar (with rounding added as an enhancement feature, cf. Stevens and Keyser (1989)), whereas Wood treats these vowels as both velar and palatal. While I do not adopt Wood's proposal⁶, I recognize the rationale behind it.

Wood observes a certain degree of crosslinguistic variation in the constriction location of the high back rounded vowels: while most /u/'s are articulated in the region of the soft palate, some have a constriction at the boundary between the soft and the hard palate, and some have a constriction right opposite the uvula. Wood's observations are confirmed by a thorough investigation of the articulatory properties of /u/ and /o/, by Jackson (1986), who interprets the extent of articulatory variation in these vowels as evidence against positing parameters of vowel articulation based on the constriction location of a vowel. Since articulatorily, /u/ and /o/ present different problems, I shall discuss the two vowels separately.

The reports of variation in the constriction location of /u/ raise the same question that the "anterior" /l/ raised earlier, namely, what is the phonological representation of /u/ articulated outside the boundaries of the soft palate, the articulatory correlate of the feature Velar Site? If it is indeed the case that all /u/-like vowels are phonologically identical, regardless of the articulatory differences among them, then this is again a problem for the view that there can be phonological features based on the constriction location of a sound.

⁶ Presumably, this proposal is intended to account for those tokens of /u/ which are articulated with a constriction at the boundary between the palatal and velar regions. I do not adopt this proposal, because, given the constraint against complex segments which involve the same Articulator or the same Site feature more than once, the "constriction" model is not capable of representing vowels with simultaneous velar and palatal constrictions, as both such constrictions would have to involve the dorsal articulator (for arguments against representing vowels with the coronal articulator see 5.4). Now, given that there is no phonological evidence from any language that /u/ acts like a palatal-velar segment, it is perhaps an unnecessary compromise to propose a theory which allows such a representation.

Let us first address the problem of an /u/-like vowel articulated with a possible palatal constriction. Jackson (1988) mentions only one such case: it is the /u/ of French, articulated near the boundary between the soft palate and the hard palate. Wood (1979) reports that the /u/ of his Egyptian Arabic informant also approached this boundary. However, these cases do not exactly parallel the case of an "anterior" /u/; here, the vowel could still be considered velar (particularly, if we adopt the quantal view of features, cf. Stevens (1972, 1989)), without raising a serious problem for the concept of the constriction location-based articulatory parameters. And from the phonological point of view, a constriction location of a vowel, ambiguous between two possible features, would seem compatible with the phonological facts which would show the vowel pattern in terms of either of the features.

A more serious problem for the phonological theory which posits the Site features would be an /u/-like vowel with the palatal constriction location and the velar-like behavior. So far, nobody has reported the existence of /u/-like vowels with the palatal constriction location, and so the predictions of the constriction model cannot be tested.

On the phonological side, there is at least one well known case of /u/ patterning with /i/ and acting like a palatal vowel: it is /u/ in Papago. In Papago (segment inventory after Maddieson (1984): i, ɪ, u, ʊ, a, ɒ, b, m, t, c, s, n, ɛ, dʒ, ɲ, d, ʃ, dʒ, j, k, g, ʔ, h, w), dentals /i/ and /dʒ/ are in complementary distribution with /ɛ/ and /dʒ/: /ɛ/ and /dʒ/ appear only before high front vowels /i/, /ɪ/, and /u/; /i/ and /dʒ/ appear in all other environments. This is shown below (data quoted from Kenstowicz and Kisseberth (1979)):

(84)(a)	činiŋ	'to move the lips'
	čikpaŋ	'work'
	čueŋle	'net bag'
	čučuŋ	'chicken'
	čukma	'dark'
	čtposid	'to brand'

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	čtɪwɪn	'to rub'
	doedʒide	'healing'
	dʒiwhiedag	'arrival'
	dʒtgos	'storm'
	dʒt-wikon	'to scrape'
	dʒuni	'dried cactus fruit'
	dʒusukaɪ	'lizard sp.'
(b)	tetel	'tendon'
	tetel	'mother's young brother'
	temš	'gums'
	tohnto	'degenerate'
	todaid	'to frighten'
	dakpon	'to slip'
	doʔeq	'mountain'

Assuming that the phenomenon illustrated above is an example of an exceptionless allophonic distribution, it must have a phonological explanation. Kenstowicz and Kisseberth (1979) suggest an analysis which relies on the characterization of /ɛ/ and /dʒ/ as redundantly [+high], in the SPE tradition; the /ɛ/, /dʒ/ alternation is then treated as an assimilation in height. However, there are good reasons to believe that /ɛ/ and /dʒ/ do not bear any tongue body specifications (cf. the discussion in 3.3.1), therefore, a different explanation for the facts in (84) should be sought.

Donca Steriade (p.c.) suggested to me that perhaps the phenomenon observed in Papago is of the same kind as the one which occurs in Japanese, where all high vowels trigger affrication of the dentals. What makes this explanation plausible, is the fact that Papago lacks surface dental affricates; it is not inconceivable then, that the dental affricates, derived from dental stops before high vowels, surface in Papago as the palatal affricates. Given this analysis, it is not necessary make unusual assumptions about the representation of high vowels in Papago.

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Let us now consider those cases in which the vowel /u/ turns up with a uvular or upper pharyngeal constriction on the X-ray. Jackson (1988) reports that while these cases are rather rare, they nevertheless do occur. For example, he reports, on the basis of X-ray tracings in Svamy and Svamy (1955), that /u/ in Chinese has an upper pharyngeal constriction. Wood (1979) reports a uvular constriction in /u/ of the Southern British English speaker who was a subject in his experiment.

I am not aware of the phonological phenomena in Chinese or Southern British English, which would help establish whether indeed the /u/ in these languages must be treated as velar despite the pharyngeal articulation. If such phenomena do exist in these languages, then they are clearly a problem for Wood's theory, and they are a problem for the view that the feature Velar Site is articulatorily sound.

The only example of an articulatorily shifted /u/ I know of is the /u/ of German, as illustrated on the tracings in Mærtens (1983):

However, the German /u/ does not behave like a velar sound. In fact, it patterns with the other two pharyngeal vowels, /ɛ/ and /a/, in at least one phonological phenomenon. This phenomenon involves dorsal fricatives in an allophonic alternation known commonly as "Achlaut": when adjacent to /u/, /ɛ/, or /a/, the dorsal fricative surfaces with a pharyngeal constriction; in all other environments, it surfaces with a palatal constriction. This is shown below:

(85)(a)	ɛxten	'to heed'	(b)	lɛ	'l'
	vɔxə	'weak'		nɪçt	'no'
	bux	'book'		mætçən	'girl'
	əux	'also'		mlɪç	'milk'

* The tracings of the German /u/ in Delattre (1971), show this vowel with a velar, not uvular constriction. The only reason for this that I could think of is that perhaps this vowel involves two constrictions which are not executed simultaneously. Since X-ray tracings are ordinarily based on still photographs, they will rarely render the articulation of a complex segment correctly.

The above data can be analyzed as follows: the underlying dorsal fricative is unspecified for the Site feature. An allophony rule spreads the Pharyngeal Site of an adjacent vowel onto the Constriction Node of the fricative. A default rule supplies the Palatal Site to the remaining dorsal fricatives.

This analysis implies that the resulting segment, which I have transcribed as a uvular, is represented with the Tongue Body constriction at the Pharyngeal Site. Even with the articulatory descriptions (cf. Delattre (1971)), it is not obvious that this is the correct representation of this sound. If German /X/ should turn out to be a true uvular, and therefore a complex segment, a different analysis of the data in (85) should be considered. A possible alternative is to treat the Achlaut in terms of a feature changing process which spreads the pharyngeal constriction of a vowel onto the palatal fricative, and whose output is later reanalyzed as a uvular.

Let us now discuss the articulatory basis of characterizing /o/ with the velar constriction location. According to Jackson (1988), /o/ is even more notorious for having variable constriction locations than /u/; here, it is appropriate to note that Jackson responds to this articulatory characterization of /o/ by Wood (1979, 1982), who designates a special articulatory region for /o/: the upper pharynx. While Jackson admits that this is the preferred constriction region for /o/, he lists a number of cases in which /o/ is documented with a constriction in the velar and in the lower pharyngeal region.

At first sight, all of these observations appear problematic for the treatment of /o/ suggested here. Since I propose to represent this vowel as a complex segment, consisting of a velar and pharyngeal constrictions, I predict that both constrictions should be reflected in its articulation. However, the reports by Wood and Jackson do not bear out this prediction.

Yet it is not the case that the vowel /o/ never appears with two constrictions on the X-ray. For example, the two constrictions

are easily observed on the tracings of DhoLuo vowels shown in Jacobson (1978). How is then the amount of variation in the observed properties of /o/ to be explained?

A number of things can conspire to produce the observed effects. First, the vowel /o/ is a complex segment with constrictions at two anatomically adjacent regions; it is not uncommon for such segments to appear with the two adjacent constrictions merged into one, somewhere along the two regions. For example, the segment such as /tʰ/ (found in Bulgarian, Russian, etc.), which must be represented phonologically with the Anterior/Tongue Blade and Palatal/Tongue Body constrictions, often appears on the X-ray with one long constriction, cf. Scatton (1984). Sometimes the two constrictions fuse articulatorily: for example an underlying /tʰ/ in Macedonian is pronounced as a palatal stop. It is not unlikely that the "fusion" effect is compounded by the fact that physically, the two articulators involved in /tʰ/ are situated on the same anatomical organ. This is also the case with /o/, articulated with the Tongue Body and Tongue Root, at the Velar and Pharyngeal Sites respectively.

Let us now consider the cases reported by Jackson (1988), in which he observed /o/ with a velar constriction, but not lower pharyngeal, or the lower pharyngeal constriction, but not the velar one. These effects are not very surprising, and can be explained easily by appealing to the possibility that in a complex segment, articulations do not always need to be simultaneous. For example, Maddieson and Ladefoged (1988) show that this is necessary in the production of complex stops, in order for the acoustic cues of two articulations to be heard.

In a segment like /o/, the sequential ordering between the two gestures may be caused by the fact that the two articulators active in the production of this vowel have little freedom from each other. Since most tracings available in the literature are based on still photographs, often only one cross-section of the segment's

articulation may be captured. In the case of /o/ it may be either the velar or the pharyngeal gesture.

The above explanation is made more plausible by the description of uvular*, consonants homorganic to /o/, by Delattre (1971). According to Delattre (p. 135, 137, etc.), uvulars, which are rarely shown on the tracings with two simultaneous constrictions, involve two gestures, that are executed sequentially. One gesture involves the movement of the tongue root horizontally towards the pharynx, and the second gesture involves the tongue rising along the pharyngeal wall towards the uvula. Since the two gestures are not simultaneous, Delattre illustrates them using two tracings.

This concludes the discussion of articulatory properties of /o/ vs. the phonological representation assigned to this vowel within the constriction model. While a straightforward support for the velar constriction in this vowel is not available, I have tried to offer an explanation as to why an X-ray of /o/ articulation might not always reveal a velar constriction.

The proposed explanation appeals, among others, to the possibility that there can be some variation between speakers or between languages, in the articulatory strategy for executing a given speech sound, particularly, when it is a complex segment. This sort of variation is found throughout phonetic descriptions. For example, the strategies for tensing vary even among the speakers of one language (English), as reported by Bell-Berti et al. (1979). And, if the feature ATR is yet another manifestation of [tense], which is suggested by the fact that no language has ever been reported to use the two dimensions, then this variation is even greater (compare, for example, the discussion of ATR vowels by Lindau (1978) and Jacobson (1978).

* Recall, that following McCarthy (1989), I consider uvulars to be complex segments, represented with a velar and pharyngeal constrictions, executed by the tongue body and tongue root respectively.

As far as the articulation of /o/ is concerned, the important conclusion is, that this variation does not exceed the boundaries imposed on this vowel by the phonological characterization: no one has yet reported the existence of an /o/-like vowel with a palatal constriction.

5.3.4 Articulatory Basis of the Pharyngeal Site in Vowels

The vowels which I propose to represent with the Pharyngeal Site are /e/, /o/, /a/, /æ/, /ɔ/, /ɒ/, etc. I have discussed the articulatory properties of /o/ in some detail in the preceding section, and concluded that the apparent counterexamples to the claim that /o/ is both velar and pharyngeal have a natural explanation.

With respect to /e/ -- vowel which I propose to represent as a complex segment with a palatal and pharyngeal constrictions, the articulatory evidence is sometimes as unclear as it is in the case of /o/. Although there seem to be no examples of the two articulations merging halfway (which indicates that there may not be /e/'s with a velar constriction), /e/ often appears to be constricted more in the palatal than in the pharyngeal region. (This might be the reason why Wood (1982) treats these vowels as palatal only.) For example, this is how /e/ in German and in French appears on tracings (Martens (1983), and Boithorel et al. (1986), respectively).

The pharyngeal constriction appears to be more pronounced in /ɛ/, the lax counterpart of /e/. This is shown both in German and in French (same references), as well as in Dholuo (Jacobson (1978)). A possible reason for this contrast might be that muscle tensing in /e/ results in an upward movement of tongue body, which also pulls the tongue root. Obviously, lax vowels do not involve the tongue bunching gesture, and as a result, they can be articulatorily truer to their phonological representation.

In languages which do not employ the tense/lax contrast, such as for example Polish, the tongue body and the tongue root appear to be equidistant from the hard palate and the pharyngeal wall

respectively (cf. Wierzbowska (1985), p. 86), and neither of the constrictions appears to be very tight.

The overall picture that emerges from these observations is that /e/ can be seen with a pharyngeal constriction whenever tenseness does not counter that gesture.

Let us now turn to the family of /ə/ vowels. On the model I am proposing, these vowels are characterized with a single constriction, executed in the pharynx. While the exact constriction location in these vowels may vary from the upper pharyngeal to mid and low pharyngeal locations, there are no /ə/-like vowels with a non-pharyngeal constriction. In 5.4, I shall argue that the variation in the constriction location in the /ə/-like vowels is a consequence of the fact that these vowels may be articulated with either the Tongue Body or the Tongue Root. Given the anatomy of the tongue, the Tongue Body constriction will most likely be opposite of the upper-mid pharyngeal wall, and the Tongue Root constriction will most likely face the lower pharyngeal wall. I will show in 5.4 that this difference is phonologically relevant.

The concluding remark for this sub-section is that while some inconsistencies between the posited phonological representations and the articulatory reality may be observed, the overall phonetic picture lends support to the phonological feature Pharyngeal Site, which maps onto the articulatory region pharyngeal wall. The observed inconsistencies have been explained as a result of one articulatory gesture overriding the effects of another.

Let us summarize the present section briefly, and comment on some of the proposals that it introduced. The main purpose of this section has been to defend the articulatory basis of the Site features in vowels; to show that these features are phonetically sound. I have considered two kinds of apparent counterexamples to this claim: cases in which a postulated complex segment was shown with a single constriction, and cases in which a segment was articulated with a constriction different from the one that was

posited. The first group of counterexamples were shown to be a result of either imperfections of still photography, which cannot represent sequentially ordered articulations, or were caused by the counteracting effect of another articulatory gesture.

The second group of counterexamples involved articulations shifted from the postulated point of articulation. In some of such cases, I have been able to show that the phonology of the segments in question reflected the real point of articulation, not the one posited. And so, an anterior /i/ in Thai has been shown to behave like an anterior segment. An anterior /i/ in Polish has been shown to pattern with the palatal and the anterior segments, but this effect has been attributed to the fact that anteriority is a derived property of the Polish /i/. A uvular /u/ in German has been shown to pattern with other pharyngeal vowels (excluding /e/ and /e/) by triggering Achlaut.

While such analyses deliver the desired results, they raise some important questions, which need to be answered before the analyses are adopted. For example, even if it is possible to represent an anterior /i/ phonologically, how is the language learner to know which /i/, an anterior, or a palatal one, he or she hears. One answer to this question might be that unless there is phonological evidence that establishes the representation of a vowel, the Site of the vowel is left unspecified, and eventually receives a default specification (e.g., Palatal for a segment articulated with the Tongue Body dominating features [+high, -back]). An unfortunate consequence of such a solution is that in languages which lack the necessary phonological reference, vowels should always surface with their supposed default values. As we have already seen in Russian, Chinese, etc., this is not true. Alternatively, one could allow the solution proposed above, with an added factor of dispersion: in languages which lack the phonological evidence, but have more than two high vowels, the default Site for /i/ would always be Anterior.

It is not clear, however, that even this solution is necessary. In the discussion of /i/-like vowels whose constriction location

approaches pre-palatal (anterior) regions, Wood (1979) points out that such vowels are characterized by a considerably higher F_2 than the palatal /i/'s. This is born out by his acoustic data for /i/ in Egyptian Arabic. Also, the /i/ in Russian, reported by Fant (1985) to have a "pre-palatal" constriction is also characterized by a higher than an average third formant (reported at 3200 cps by Fant (1980), p. 109). Wood also points out that an /u/-like vowel with a post-velar constriction is likely to surface with an F_2 lower than an ordinary, velar /u/. The acoustic data for German (Ferrari Disner (1983), p. 38) show that the /u/ in this language is indeed characterized by a lower F_2 than its English counterpart. What these facts show, is that "displaced" vowels need not rely on phonological evidence for their articulatory reference, because they should be perceived as acoustically distinct by the language learner.

Given that /-i/ (an anterior /i/) is acoustically distinct from /i/ (a palatal /i/), to the extent that the language learner can assign a correct representation to these vowels on the basis of the acoustic signal, the next question that comes to mind is why /-i/ and /i/ are never contrasted in the same language (at least not in any known language). Since such a gap is not likely to be accidental, it deserves an explanation.

The only plausible explanation I can think of is that while the acoustic signals associated with these sounds are distinct enough to be correctly classified by a language learner (or even by an adult, who easily detects "foreign accent"), the acoustic distance between them may not be sufficient to support a phonemic contrast.

Of course, this is only a hypothesis, which can only be confirmed by a broad scale study comparing acoustic distances among the sounds which languages ordinarily contrast, with the acoustic distance between /-i/ and /i/, velar and uvular /u/, and so on.

As a final remark, I would like to point out that cases in which two phonologically distinct representations fail to support a

phonemic contrast are not limited to the ones described above. For example, any grammar should be capable of assigning distinct phonological representations to a palatalized nasal (n'/η), a coronal palatal nasal, and a palatal dorsal nasal. As far as I know, no language employs this three-way contrast.

5.4 Articulator Features in the Representation of Vowels

In this section I discuss various issues relevant to the concept of representing vowels in terms of Articulators -- phonological features introduced by Sagey (1986), whose phonetic basis are the organs active in the constriction gesture. While the anatomical organs which execute the constrictions are the lower lip and the tongue, Sagey adopts the idea in Chomsky and Halle (1968), developed more explicitly in Halle (1983), to further subdivide the tongue into parts that can move relatively independently of each other. And so, she posits the coronal articulator, whose anatomical correlate is the tongue tip with the tongue blade, and the dorsal articulator, whose anatomical correlate is the tongue body. Recently, this system of articulators has been enriched by the addition of the radical articulator, which corresponds to the root of the tongue, by Ladefoged and Maddieson (1986).

I adopt Sagey's concept of the articulator, and with the modification introduced by Ladefoged and Maddieson (1986), I assume that there are four distinct articulator features: Lower Lip, Tongue Blade, Tongue Body, and Tongue Root. Below, I discuss various issues related to representing vowels in terms of Articulator features: I consider the phonetic basis of these features whenever a controversy exists, and I discuss the role of the Articulators within the feature system which already contains the Sites.

5.4.1 The Tongue Body

I assume that the vowels which are represented in terms of the Tongue Body are: i/η , i/η , i/η , i/η , i/η , and i/η , i/η .

i/η , i/η . This leaves i/η , and possibly, its round counterpart, i/η , as the only vowels not represented with this articulator.

I follow the tradition of associating features $[high]$ and $[back]$ with the position of the tongue, and after Sagey (1988), I assume that these features are dominated by the dorsal articulator (the Tongue Body). I leave out of the present discussion the features $[tense]$ and $[ATR]$, since it is not clear to me where these features (or features, should $[ATR]$ turn out to be an alter ego of $[tense]$; see Halle and Clements (1983) for a suggestion to this effect) belong in a segmental tree.

In what follows, I discuss some of the articulatory aspects of $[high]$ and $[back]$, and, on the phonological side, I present arguments that these features are needed for the purposes of vowel representation, in addition to the Site features.

5.4.1.1 The Feature $[high]$

While participation of the tongue body in vowel production is rarely if ever questioned, the articulatory basis of the features

- * i/η represents a mid vowel higher than i/η .
- * At this point, I refrain from any commitment to the feature $[low]$. Later on, I consider various pros and cons of including $[low]$ among the phonological features.
- * Neither phonological nor phonetic considerations are helpful in determining the status of $[tense]$ and $[ATR]$. For example, if these are two different features, it is not clear why they cannot co-occur in a single language. If, on the other hand, they are a single feature, their articulatory diversity becomes puzzling: when feature $[tense]$ was originally introduced (Jakobson and Halle (1956)), it was defined in terms of the tongue muscle tensing. Since then, a number of different proposals for different languages have been made. Ladefoged (1964) has pointed out that the mechanism behind an apparent tense-lax distinction in 1960 is the tongue root advancement. Lindau (1978) has discovered that the mechanism of tongue root retraction may be accompanied by larynx raising in Aken. Jakobson (1970), who studies the correlates of the harmonic feature in Dholuo reports that speakers are divided into two groups, depending on whether they use tongue height or tongue root advancement for the same harmonic effect. Interestingly, he does not observe larynx movement associated with the harmonic feature. Bell-Berti et al. (1979) report that the speakers of English are divided into different categories, depending on whether they use tongue height or muscle tensing to produce tense-lax contrast.

which are dominated by the Tongue Body articulator are not always obvious: the tongue arch model, despite its success in phonology, has been criticized for its articulatory inaccuracy, virtually since its very beginning. The main objection raised by the researchers (Meyer (1910), Russel (1928), Joos (1948), etc.) has been that the model incorrectly predicts the lax vowel /ɪ/ to have a higher tongue arch position than the tense vowel /e/. On the basis of the articulatory data from German, Dutch, Swedish, and English, they have shown that the vowel /ɪ/, supposedly characterized by [+high] tongue position, consistently appears with the tongue body lower than the tense vowel /e/ in languages that contain both.

The relationship between the real and the phonological height of vowels has been investigated more recently by Sidney Wood (1979, 1982), whose data consist of multiple X-ray tracings of vowels from 15 languages, some of them obtained with modern cineradiographic methods to assure high accuracy. Wood's study confirms the observation made by Meyer, Russel, Joos, etc., that the tongue height predicted by the tongue arch model does not correspond to the phonetic data.

Wood considers this flaw sufficient to dispense with the tongue arch model. Instead, he proposes a model of vowel articulation which characterizes vowels in terms of the constriction location, degree of jaw opening, and muscle tenseness (see section 5.1). While I adopt Wood's proposal to treat vowels in terms of the constriction location features, I take a more sympathetic view of the tongue arch model.

As noted by Halle (1983), the tongue arch model has persisted as the basis of vowel description in phonology and phonetics textbooks, despite the fact that the controversy involving the feature [high] has been known since the beginning of the century. Halle points out that there is a very good reason for the model's popularity, namely, grammars of languages provide many examples of phonological rules which activate the [height] feature, and which treat vowels /i/, /ɪ/ as high, and /e/, /ɛ/ as non-high.

In similar vein, there are many examples of rules (e.g., height harmonies) which group vowels /i/, /u/ on one hand, and /e/, /ɛ/ on the other hand, into natural classes. The model which characterizes vowel articulation solely in terms of the constriction location, cannot represent vowels like /i/ and /u/ as members of a natural class.

Obviously, Wood (1982) is not unaware of this: while he rejects the tongue height feature in phonetics and phonology, he proposes to account for the phonological generalizations which this feature handles, in terms of a feature [open], whose articulatory basis is the degree of jaw opening. He characterizes /i/, /ɪ/, /u/, /ʊ/, etc., as [-open], and /e/, /ɛ/, /ɔ/, /ɒ/, /a/, /ɑ/, etc., as [+open].

However, the feature [open], while it may appear to solve the articulatory difficulties of the feature [high], has problems of its own: in the every-day speech, the jaw movements accompany vowel production, generally, in conformity with Wood's predictions. However, experiments in which subjects have been asked to pronounce different quality vowels while their jaws were locked in a fixed position (cf. Linblom (1989)), show that the variation in jaw opening might facilitate the pronunciation of different quality vowels, but that it is by no means a necessary component of vowel production*.

The feature [open] faces even greater difficulty in phonology, particularly in the phonology which posits highly structured representations. Since it is not associated with any Articulator (nor with a Site, if the constriction model is considered), its only possible location can be the Root Node (or at least a node which dominates the Constriction Node). In such a case, the feature [open] ought to be equally relevant in the representation of segments articulated with either Lower Lip, Tongue Blade or the Tongue Root,

* I am grateful to Ken Stevens for pointing this out to me, and for demonstrating the experiment

as it is in the representation of sounds articulated with the Tongue Body. However, as shown in 2.3, the height phenomena do not occur with non-dorsal segments: neither coronals nor labials ever trigger height changes in vowels. And, as I will show later on, segments represented with the Tongue Root articulator are equally neutral w.r.t. height phenomena.

Let us summarize the discussion so far: while phonological considerations argue for including the tongue height feature in the representation of vowels, articulatorily the tongue arch model appears to be inaccurate, at least as far as this feature is concerned. Even though there appears to be no substitute for [high] (in view of what has been observed about the degree of jaw opening feature of Wood (1982)), the articulatory inaccuracy nevertheless poses a problem for a model of feature representation which employs the tongue body features (such as, for example, the constriction model).

A possible solution to this problem has been suggested by Fischer-Jørgensen (1985), who also recognizes the explanatory power of the feature [high], and defends the status of this feature against Wood's criticisms. She points out that unexpected differences in tongue height are observed only when tense vowels are compared with lax vowels, never when the vowels are compared within the tense and lax sets. She suggests treating tenseness as a separate dimension, independent of height; on this view, /ɪ/ and /ɔ/ are not compared with /e/ and /o/, but with /e/ and /ɔ/ against which they are indeed [+high].

In a way this explanation shifts the problem elsewhere instead of solving it -- after all the feature [tense] is not well understood either. However, it is acceptable in so far as there does exist a phonological feature [tense], which articulatorily interacts with the feature [high]. Since this explanation salvages the concept of representing vowels in terms of the feature [high], associated with the positions the Tongue Body articulator assumes during the production of different vowels, I adopt it.

I now turn to the question of phonological motivation for the feature [high]. Since this feature is well established in phonology, all that remains to be shown is that it is needed for the purpose of representing vowels in addition to Site features.

Traditionally, the feature [high] has divided vowels into two classes: [+high] i, ɪ, u, ɔ, ü, w, ʔ, etc., and [-high] e, ε, o, ɔ, ö, ʌ, as well as the so called "low" vowels. I adopt this distinction with one exception, namely, I do not treat the vowel /ə/ in terms of the feature [high], since I do not consider it to be articulated with the Tongue Body.

Given the system of Site features proposed in this thesis, the need for the feature [high] is not immediately obvious, and must be reexamined. While there is little doubt that phonologies of languages require this feature (or its equivalent) to explain such phenomena as height harmonies (cf. the [+high]/[-high] vowel harmony in Pasiego (McCarthy (1984)), [+high] vowel harmony in Menomini (Bloomfield (1939), Cole (1986), Steriade (1987))), or height disharmonies (cf. height disharmony in Ngbaka and in Ainu (Ito (1984))). It is reasonable to ask whether the system of site features does not make this feature superfluous.

An examination of the representations which the constriction model assigns to vowels reveals that the value of the feature [high] for any vowel can be predicted from its constriction location(s): all vowels with the pharyngeal component (e, ε, o, ɔ, ʌ, ö, ə, ɔ, etc.) are [-high], and all vowels without the pharyngeal component (i, ɪ, u, ɔ, ü, ʔ, etc.) are [+high]. This shows that the value of [high] is redundant in vowels. At the same time, however, it is clear that only those segments which share the pharyngeal specification can be characterized as a natural class without a reference to height. Segments which are redundantly [+high] do not share a phonological feature which would characterize them as a natural class, and which could replace [high]: /ɪ/, /ü/, and /ɪ/, are Palatal/Dorsal,

/u/, /ɪ/, and /o/ -- Velar/Dorsal, etc. Since there exist phenomena (e.g., vowel harmony in Pasiego (McCarthy (1984))) in which both values of [high] are active, it follows that this feature must remain in the representation of vowels.

5.4.1.2 The Feature [back]

Traditionally, the feature [back] groups vowels into the following classes: [-back] i, ɪ, e, ɛ, ü, ö, œ, etc., and [+back] ɯ, u, o, ɔ, etc. As far as I know, there is little controversy concerning the articulatory accuracy of this feature*. Therefore, this section will be concerned solely with the question whether there exists independent motivation for [back] in the feature system which contains the Sites.

A comparison between the segments traditionally treated as [-back] (i, ɪ, e, ɛ, ü, ö, œ, etc.) and the segments which I propose to represent with the Palatal Site (ɨ, ɨ, e, ɛ, ü, ö, etc.) reveals that the two sets overlap considerably. In fact, only the vowel /œ/ remains as a [-back] segment which is not palatal. In a case like this it is reasonable to ask whether the feature [-back] could, in the interest of economy, be replaced with the feature Palatal Site.

I want to suggest that despite a near-perfect overlap between the [-back] and palatal segments, there are good reasons for maintaining the feature [back] in addition to Palatal Site.

In order for the Palatal Site to take over [back], a number of conditions would have to be met: first, it would have to be shown that all processes analyzed earlier in terms of [-back] -- a feature dominated by the Tongue Body Articulator -- can be handled in terms of a feature which refers to the constriction location. Second, it would have to be shown that there are no processes which require

* Not counting /u/ in languages like German.

* While Wood (1982) rejects it (see 5.1), he does so only because he rejects the tongue arch model, with which this feature is associated.

the feature [+back]. Finally, /œ/, since it patterns with palatal vowels (see below), would have to be treated as a palatal segment, and represented in such a way as to contrast with /e/ and /ɛ/. Below I show that none of these conditions can be met.

In 7.1, I argue that because of their different positions in the segmental tree, the two types of features -- an Articulator-dominated feature and a Site feature -- should reveal rather different behavior in phonological processes. Since the Site feature is dominated directly by the Constriction Node, and since all (fully specified) segments contain this node, then, on the assumption that all phonological processes are strictly local (cf. Steriade (1986)), there should be no cases of "segment skipping" spreading of this feature. This restriction does not apply to the articulator-dominated features, in this case the feature [back]. Since it is dominated directly by the Tongue Body, it may propagate across any segment that is not specified for the Tongue Body articulator. Evidence from languages such as Chamorro (Topping (1968)), or Hungarian (Kiparsky (1986), Vago (1976), Ringen (1980), etc.), in which two or more vowels agree in backness (or palatality) without involving the consonants, argues for the feature [back] independent of Palatal Site. Clearly, the harmony processes in such languages cannot be reanalyzed in terms of the feature Palatal Site.

Another argument against eliminating the feature [back] comes from languages in which [+back] is active in phonological processes. An example of such a language is Finnish, for which a process of [+back] harmony has been motivated by Kiparsky (1981) (as well as Steriade (1987), who adopts this aspect of Kiparsky's analysis). Since vowels such as /u/, /o/, and /ɑ/ do not share the constriction location or the height feature, they can be characterized as a natural class only with the feature [+back].

In a similar fashion, the vowel /œ/, and its patterning with palatal vowels in the harmony processes (e.g., Chamorro, as analyzed by Kenstowicz and Kisseberth (1979)), constitutes a problem for a feature system without [back]. There are both phonetic and

phonological reasons for not treating it as a palatal vowel: phonetically -- it does not involve a palatal constriction (c.f. Wood (1982)); phonologically -- even though it patterns with palatal vowels in the harmony processes, it fails to trigger palatalization*. Therefore, it cannot be represented with the feature Palatal Site. The only other feature that can place it among vowels such as /e/, /i/, /u/, etc., is the feature [-back].

On the basis of the above arguments it is possible to conclude that the feature [back] is needed for the purposes of vowel representation in addition to the Site features.

5.4.1.3 The Feature [low]

In this section I argue against the feature [low]. I show that the natural class effects among segments specified as [+low] can be captured by the feature Pharyngeal Site, and I reanalyze an apparent example of the phonologically active [-low].

To my knowledge, there are no attested cases of [+low] vowel harmonies. No language has a rule which converts all vowels to [+low] whenever there is /a/, /æ/ or /ɑ/ in a word. This is an unexplained gap if [low] is a feature dominated by the Tongue Body Articulator.

Dissimilatory processes do occur among the so called "low" vowels. For example, in the Bizcayan dialects of Basque (cf. de Rijk (1970)), the first of two adjacent /a/'s turns into /e/, e.g.,

(86)	alabe bat	'one daughter'	alabe-a	'the daughter'
	neake bat	'one girl'	neake-a	'the girl'
	isere bat	'one sheet'	isere-a	'the sheet'

A similar process occurs in Woleaian (Sohn (1975)); however, in this case, a consonant may intervene between the two vowels:

(87)	metel	'my eyes'	metememl	'our eyes'
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* The representation of /æ/ is discussed in more detail in 5.6.

jeferə	'shoulder'	yəferəl	'my shoulder'
yəferememl	'our shoulder'		

It is possible to analyze the dissimilation phenomena illustrated above as an OCP effect applying at the Pharyngeal Site tier, without reference to the feature [low]. Of course, such an analysis raises an obvious question, namely why does the dissimilated vowel turn into /e/, a segment which contains the offending pharyngeal component (given the representation of /e/ proposed in this thesis)? A plausible explanation for this fact might be that the first step in the dissimilation process is the deletion of the Pharyngeal Site of the first vowel. This rule produces a vowel with an unspecified Site, a schwa (see 7.5). The ultimate conversion of /a/ to /e/ can be attributed to the fact that in the five vowel systems of Basque and Woleaian, /e/ is articulatorily closest to /ə/; it is redundantly [-high], and it does not involve lip rounding.

Stronger support for the feature [low] comes from the processes which raise /a/ in the environment of non-low vowels. An example of such a process is found in a great number of Basque dialects (cf. de Rijk (1970), Hualde (1988)). In those dialects, vowels /i/ and /u/ raise the following /a/ (either adjacent or across a consonant) to /e/. Neither /e/ nor /o/ trigger this process:

(88)	egun-e	'the day'	giʒon-a	'the man'
	erl-ke	'throwing stones'	petote-ke	'throwing a ball'

The raising phenomena of this sort seem to imply an asymmetry between the "+" and the "-" value of the feature [low]. On the one hand, the absence of "lowering" harmonies suggests that there is no feature [+low]; on the other hand, the raising of /a/ after high vowels seems to suggest that there is a feature [-low]. While the possibility that there might be such a feature cannot be completely

* Most likely, the same mechanism is responsible for the fact that in many languages, /ə/ surfaces as an epenthetic vowel, despite the fact that it is not simple from the articulatory point of view.

ruled out, a reanalysis of the data in (58) above would be more welcome on principled grounds.

A possible way to analyze the data in (58) without reference to [-low] would be to assume a process which spreads tenseness of /i/ and /u/ onto /a/. Since there is no [+tense] counterpart of /a/ in Basque, tense /e/ is the next plausible alternative.

The above analysis, while not particularly well motivated on the grounds of Basque (except for the fact that the mid front vowel in this language is indeed [+tense]) (cf. N'Diaye (1970)), and not [-tense] as would generally be expected in a five vowel system, cf. Crothers (1978)), receives more support from the comparison with Igbirra -- another language in which /a/ is raised to /e/.

In Igbirra (vowel inventory: i, i, e, e, u, o, o, ɔ, a), the low vowel is raised not just in the environment of high vowels (in fact the lax high vowels have no effect on it), but before any tense vowel of the language. This is shown below (I quote the data after Bissantz et al (1987)):

(59)	mezi	'i expect'	mezi	'i am in pain'
	meze	'i am well'	maze	'i agree'
	meto	'i arrange'	meto	'i pick'
	metu	'i beat'	meto	'i send'

In (59), the 1st person prefix is shown to alternate between /e/ and /a/ in what appears to be a clear example of a tenseness harmony. What argues against the laxing analysis is the fact that /a/ has a lax counterpart in the language, /e/. Therefore, it would be difficult to derive /a/ from /e/ via a laxing rule. Deriving /e/ from /a/ via tensing is simpler, because /a/ has no tense counterpart in the language. Presumably, the output of the tensing of /a/ is reanalyzed so as to conform to the phonemic inventory of the language.

The Igbirra facts constitute an example of a process which has a surface effect of raising /a/ to /e/, in which the feature [-low] plays no role (as shown by the fact that /a/ co-exists with non-low

lax vowels in the same word). These facts make the analysis of vowel raising in Basque suggested above more plausible.

In view of what has been discussed in this section, the phonological behavior of the feature [low] can be summarized as follows: in its positive value, [low] fails to pattern like an articulator-dominated feature -- most notably, it fails to trigger vowel harmonies. Indeed, [+low] acts more like a feature dominated directly by the Constriction Node -- it does not skip segments when it spreads, yet it is viable across non-low segments in dissimilatory processes. In its negative value, [low] does act like an articulator-dominated feature, in that it spreads in the harmonic fashion. However, it fails to pattern with [-low] in that it never (at least to my knowledge) participates in a dissimilatory process. In other words, there are no examples of /i/, /u/, /e/, or /o/ turning to /a/ when followed by either /i/, /u/, /e/, or /o/.

This behavior of [low] makes it a very peculiar feature, which does not resemble any other feature in the system. Of course, the aspects of the behavior of [low] which appear peculiar in a single articulator-dominated feature, are quite consistent with the behavior of two features: Pharyngeal Site and [tense]. A reanalysis of [+low] in terms of the Pharyngeal Site explains why there are no vowel harmony processes which spread [+low] -- after all, no Site feature acts in such a way. A reanalysis of [-low] in terms of [-tense] captures the facts of vowel raising (as in Basque and Igbirra), and explains why [-low] does not behave in any way like [+low]. With these reanalyses, the motivation for the feature [low] disappears.

5.4.2 The Lower Lip

While the role of the lower lip in vowel production is uncontroversial, it is not an easy task to demonstrate that this articulator is active in vowel phonology. Obviously, this is not because labial vowels are somehow immune to phonological processes. However, in order for the processes which manipulate

such vowels to be unambiguously interpreted as involving the Lower Lip Articulator (and not the Labial Site), they would have to occur in languages in which the class of sounds articulated with the Lower Lip is larger than the class of sounds involving the Labial Site. At this point, I am not aware of the examples of the labial phenomena in languages that meet this condition. However, most likely, this gap is a mere accident, since there are clear cases of processes involving labial consonants which must be analyzed in terms of the Lower Lip Articulator (see 2.1).

5.4.3 Tongue Blade*

Neither the IPA feature system nor the original SPE proposal have made allowances for treating vowels in terms of features associated with the tongue blade/tip articulator.¹ The earliest proposal to characterize vowels in terms of coronality is due to Clements (1978), who characterized front vowels as [+coronal]. Ito and Mester (1989) interpret Clements' proposal within the hierarchical system of segment representation of Sagey (1988).

The main motivation behind Clements' (as well as Ito and Mester's) proposal has been to provide an adequate account of the palatalization phenomena. Clements points out that the invariability of these phenomena with respect to the trigger (front vowels) and the output (coronal consonants), as well as the frequency of occurrence, suggest a possibility of an assimilation-based analysis. Since such an analysis is not available within the SPE feature system (as front vowels and palatal consonants do not form a natural class in this system), he proposes to remedy the situation by treating front vowels as coronal (in addition to [-back]), and palatalization as coronalization which preserves the consonant's specification for [anterior].

*The discussion in this section is a shortened version of the discussion in Goracke (1989).

¹With a possible exception of the so-called "retroflexed" vowels which have been characterized by some (e.g. Ladefoged (1982)) as retroflex.

The proposal to treat front vowels as coronal seems problematic from the phonological point of view. First, it draws support from the definition of the feature [coronal] proposed in SPE, according to which "coronal sounds are produced with the blade of the tongue raised from its neutral position" (cf. Clements (1978), Ito and Mester (1989)). However, such a use of [coronal] ignores what appears to be a universal restriction on the articulatory features, namely, that they may be phonologically relevant only if they characterize articulatory states at the constriction. Since the tongue blade does not participate in the constriction gesture of a front vowel (as attested by the X-ray evidence), the feature [coronal] would have to constitute the sole exception to the above generalization.

According to Clements (1978) and Ito and Mester (1989), front vowels are both [+coronal] and [-back]. In Sagey's (1988) terms this translates into two possibilities: either front vowels are both coronal and dorsal, with the Coronal Node dominating the feature [anterior], and the Dorsal Node dominating [back] and [high], or else, the Coronal Node is the seat of all front vowel features, including [high] and [back] (in fact, Ito and Mester adopt the latter view).

Both views have obvious undesirable consequences: if front vowels can be coronal in addition to being dorsal, why cannot back vowels be coronal as well (and also trigger palatalization)? If, on the other hand, front vowels are just coronal, and back vowels are just dorsal, then, given the treatment of complex segments proposed by Sagey (1988), based on the insight that any two independent articulators can be combined in a complex segment, we should expect to find complex vowels which are both front and back. Other questions concern the representation of the palatalized dentals, found in Russian, Bulgarian, etc. (whose existence Ito and Mester deny), the behavior of the coronal vs. palatalized segments in vowel harmonies (simple coronal sounds do not block the spread of [-back] harmonies, but the palatalized segments (including the palatalized

coronals) do (cf. the analysis of Turkish by Clements and Sezer (1982), and the discussion in 3.3).

Even this short list of problems suggests that the treatment of front vowels as coronal cannot be easily incorporated into modern day phonology. Therefore, it is reasonable to ask whether there exists sufficient phonological motivation for such a proposal. Both Clements and Ilic and Mester justify their proposal by demonstrating its potential for solving the problem of palatalization. As far as I know, this is the only motivation that has ever been proposed for the coronality of front vowels.

This motivation loses its strength when considered in the framework of the constriction model. Since this model recognizes phonological features based on the constriction location of a segment, it provides the means of analyzing the palatalization phenomena (see Goreska (1987)) in a way that captures their assimilatory character, without assuming that front vowels are coronal. Briefly, the analysis proposed in this thesis treats palatalization as a process which spreads the palatal constriction of a front vowel onto the root node of an adjacent consonant. The immediate output of this process is a palatalized segment. If such a segment occurs in the underlying inventory of the language -- nothing happens. The reduction of a complex segment to a simple palatal sound takes place if a language lacks the doubly articulated segment. Whether this sound is coronal or dorsal, depends again on the inventory of the language. The analysis I propose predicts that if a given language has dorsal palatals, then they will constitute the final output of palatalization (this is what happens with Margi velars (Hoffman (1963)), and with Basque dentals (Saltarelli (1988)), even though both languages have the coronal palatals too. If the language lacks the dorsal palatals, the default articulator for the Palatal site becomes the Tongue Blade.

The constriction model is also capable of explaining the cases of "anteriorization", quoted by Clements (1976) as a primary evidence for the coronality of front vowels. An example of such a

phenomenon, involving a k/ʈ alternation before front vowels in Polish, is discussed in 5.3.2.3. The alternation is analyzed along the lines proposed for palatalization, except that the vowels triggering anteriorization are treated as Anterior, not Palatal.

Finally, there exist phenomena involving front vowels and anterior consonants, which can be explained only by appealing to the constriction location features. An example of such a phenomenon is the velarization process affecting /ʃ/, /s/, and /ʈ/ before front vowels in Thai (discussed in 5.3.2.1). This phenomenon cannot be explained by appealing to the coronality of front vowels, because the class of consonants which are velarized includes a labiodental.

In view of what has been said in this section, it is clear that the constriction model does not need to appeal to the coronality of front vowels in order to explain the palatalization phenomena.

5.4.4. The Tongue Root

The treatment of the Tongue Root articulator I am suggesting departs considerably from previous treatments, the main difference being that I do not consider this articulator to be uniquely associated with the feature [ATR]. Instead, I consider the Tongue Root to be an articulator in the same sense that the Tongue Body or the Tongue Blade is -- an Articulator capable of executing a constriction gesture. Among the vowels represented with this articulator are /e/, /ɛ/, /o/, /ɔ/, and /a/.

Since the tongue root can form a constriction against the pharyngeal wall (= Pharyngeal Site) only, it is not possible to argue for the feature Tongue Root on the basis of the natural class phenomena. However, there are other considerations which support positing this feature.

One of the most puzzling problems for a theory of segment representation is the existence of the so called "neutral" segments -- segments which fail to undergo a harmony process, and which are transparent to it. In vowel harmonies, the vowel /a/ is most

commonly found to act like a neutral segment. Yet it is by no means a rule for /a/ to behave in such a way.

In 7.1 I propose to approach the problem of neutral segments in terms of the missing "landing site": a feature may be allowed to propagate across a segment that lacks the node to which this feature could attach. While this concept does not explain all cases of neutral segments, it captures rather elegantly the general facts of consonantal and vowel harmonies (see 7.1).

It appears to me that this concept can be profitably extended to explaining the behavior of the vowel /a/. In cases in which it acts like a neutral segment and in cases in which it participates in the harmony (disharmony) processes, I want to suggest that in those cases in which the vowel /a/ acts like a neutral segment w.r.t. to the processes which spread the features dominated by the Tongue Body, it lacks the "landing site" onto which the harmonic feature could spread. In such cases, the vowel /a/ is to be analyzed as involving the Tongue Root as an active Articulator. Whenever /a/ participates in processes which spread either [back] or [high], it is to be analyzed as involving the Tongue Body as an active Articulator.

Let us consider some examples to which these concepts can be applied. In the Pasiego dialect of Montañas Spanish (analyzed by McCarthy (1984), Steriade (1987)) (vowel inventory (McCarthy (1984)): i, e, u, o, ɔ, a, and A, a tense counterpart of /a/) a height harmony spreads either [-high] or [+high] specification of a stressed vowel onto a non-low vowel. As shown below, the vowel /a/ (as well as its tense counterpart /A/) is transparent to the spread of the harmonic features, and fails to spread any value for height when it appears in a stressed position:

(30)	blb-ís	'drink'	sint-ís	'feel'
	beb-émus		sent-émus	
	beb-émus		sint-áis	
	el-mái	'the evil'	il mAdíro	'the log'

en kwénte 'because of' in 1) kaifxu 'in the lane'

In Ngbaka (see Steriade (1987), and references there), (vowel inventory (Steriade (1987)): i, u, e, ɛ, o, ɔ, a; plus the same series with length), vowels within a single morpheme are subject to the following restrictions: vowels of the same height can cooccur only if they agree in all other features; if the vowels are not identical, they must be of a different height. The vowel /a/, though, can cooccur with any other vowel.

Steriade (1987) explains the neutrality of /a/ in 'these cases as follows: since the vowel /a/ is [+low], it's specification for [high] is predictable (given that there are no [-high][+low] segments), and does not need to be present in the Underlying Representation. The absence of this specification explains the fact that the vowel /a/ cannot be subject to constraints which apply to [-high] segments, the fact that it cannot spread [-high], and its transparency to the spread of [-high]".

This type of explanation is not available within the framework which does not employ the feature [low] (see 5.4.1 for the arguments against this feature). If /a/ is not [+low], then its [-high] specification ought to be determined by the same principles by which /e/ and /o/ are [-high]. In fact, this is how I propose to treat all dorsal vowels with a Pharyngeal constriction.

The neutrality of /a/ w.r.t. height (dis)harmony in Pasiego and Ngbaka can be explained within the constriction model under the assumption that /a/ lacks the proper landing site for the feature [high] to spread on. This would be the case if the vowel /a/ were articulated with the Tongue Root rather than the Tongue Body. Such a vowel could never bear the height or the backness specification (both features being the daughters of the Tongue Body Node), and it would always be transparent to processes spreading these features.

Given the above proposal, one would predict that the vowel /a/ should never be affected by the processes spreading the Tongue Body

features. Obviously, this prediction is false, because there are languages in which /a/ apparently does participate in such processes. Consider, for example Turkish (vowel inventory (Clements and Sezer (1982)): i, ü, u, w, e, ö, o, a, plus the same series with length), where /a/ alternates with /a/ in a backness harmony:

(91)	oda-dən	'room'	dere-dən	'river'
	oda-lar		dere-lər	
	oda-je		dere-je	

In order for the treatment of Pasiego and Ngbaka suggested above to go through, there would have to be two varieties of /a/ -- one articulated with the Tongue Root (as in Pasiego and Ngbaka), and one articulated with the Tongue Body (as in Turkish).

At first sight, such a move may appear to be unwarranted -- after all, it introduces a phonological distinction which is never (at least to my knowledge) used to support a phonemic distinction. However, the anti-juditory data make this treatment of /a/ credible. Comparative articulatory evidence suggests that constriction location for /a/ may vary between the mid-to-upper pharynx (as in French (cf. Botherel et al (1988)) or Turkish (cf. Skladis-Konstantinidis (1981))), and the lower pharynx (as in Polish (cf. Wierzchowska (1985))). In the former, a ball-shaped tongue executes the constriction; in the latter -- the base of the tongue is an active articulator. These differences correspond to different acoustic signals: for example, the Turkish /a/ has a fairly low F₁ (approximately 500 cps, judging from the spectrograms in Skladis-Konstantinidis (1981)), while the F₁ of the Polish /a/ is approximately 800 cps (Wierzchowska (1985)).

The treatment of /a/ suggested here predicts that the variant with a low pharyngeal constriction should always be neutral to the processes spreading the features dominated by the Tongue Body Articulator, and the variant with the upper pharyngeal constriction should participate in such processes. Unfortunately, the

articulatory/acoustic data from languages with the two types of harmonies are too scarce to verify this prediction.

No articulatory or acoustic data are available for the 'asiago variety of Montañes Spanish. If, however, the 'low' vowel in this dialect of Spanish should turn out, not implausibly, to be the same as the 'low' vowel in another dialect of Spanish -- Castilian, then, given the acoustic measurements in Morimoto (1988), according to which the F₁ of /a/ pronounced by a male speaker of Castilian is 780 cps, the Montañes /a/ would be considered a Tongue Root vowel. Of course, without the actual data -- this is pure speculation.

5.5 Evidence for the Constriction Node in Vowels

I argue for the presence of the Constriction Node in the representation of vowels on the basis of the phenomena which can be analyzed only in terms of a node that maps onto a single articulatory gesture.

One of the most clear examples of the phenomena in which a single constriction node of a vowel is phonologically active, is palatalization. In Gorecka (1989) I show that palatalization of consonants can be analyzed only as a process which spreads a Palatal constriction of a vowel onto the Root Node of a consonant.

Vowel coalescence and vowel simplification phenomena provide particularly strong support for the Constriction Node, and for the vowel representations proposed in this thesis. These phenomena have long been a problem for the model of vowel representation which can characterize vowels solely in terms of the tongue body and the labial features (this applies to both the IPA and the SPE treatment of vowels). Below I analyze examples of these phenomena, and show that they are best explained in terms of operations on phonological constituents which correspond to the constriction gestures.

5.5.1 Vowel Coalescence

Vowel coalescence is a common phenomenon in languages of the world. It is virtually a rule in the Bantu languages, but it is by no means confined to this family (cf. the discussion in Schane (1987)). Most commonly, vowel coalescence converts the sequences /a/ + /i/ and /a/ + /u/ to /e/ and /o/ respectively.

On the constriction model, this phenomenon has a straightforward explanation: two simple segments merge and give rise to a doubly articulated segment via a process which collapses identical nodes, and computes non-identical nodes.

While the coalescence phenomena can be handled as a single process within the IPA or SPE framework (with obvious difficulties arising in predicting the feature output from the input that contains a [+high] and [+low] element¹), a very similar phenomenon, which involves assimilation rather than the merger of the segments, cannot receive such a treatment within those frameworks.

As an example, consider the following process in Tunica, discussed by Kenstowicz and Kisseberth (1979), on the basis of the data in Haas (1940). In Tunica, the sequence /ia/ is realized as /e/, and the sequence /ua/ is realized as /o/. Such sequences arise when a quotative prefix /-ani/ attaches to words that end in /i/ or /u/:

- (92) mlii + ani ---> mlieni 'it is red'
 niku + ani ---> nikuani 'he says'

Kenstowicz and Kisseberth point out that this phenomenon cannot be treated as a simple case of segmental fusion, but rather, it must be analyzed as a two-step process, involving an assimilation and a deletion of one of the vowels. They argue for this analysis on the basis of the fact that the alternation takes place even the vowels /i/ (e) and /a/ or /u/ (o) and /a/ are separated by a glottal stop. This is shown below:

¹ The reason why such difficulties do not need to arise on the constriction model is that (first, this model does not recognize the feature [low] (cf. the discussion in 5.4.1), second, both height values are predictable in this model and do not need to be present in the UR when coalescence takes place.

- (93) po + ?ekɪ ---> pɔʔɛkɪ 'she looks'
 pi + ?ekɪ ---> pʔɛkɪ 'she emerges'

On the constriction model, the above phenomenon involves the spread of the Constriction Node of a vowel onto the following /a/. The only articulations that can spread, are naturally the Palatal and the Velar one. The fact that the glottal stop does not inhibit this process, but all other consonants do, can be explained on the assumption that unlike other consonants, /ʔ/ lacks place features in the Underlying Representation (cf. Steriade (1986)).

Neither the IPA nor the SPE² frameworks can treat the facts in (92-93) in terms of a single process, as the only feature that /i/, /u/, /e/ and /o/ share within these frameworks is [-low]: obviously, this feature cannot explain why /a/ turns into /ɔ/ after /u/ and /o/, and into /e/ after /i/ and /e/.

5.5.2 Vowel Reduction

Vowel reduction phenomena constitute a different type of evidence for the constituent Constriction Node in the representation of vowels. Reduction occurs generally in unstressed vowels, and most commonly, converts a complex vowel (either /e/ or /o/) into a simple vowel (/i/ (ɪ) and /u/ (ʊ) respectively). Some examples include vowel reduction in Syrian Arabic, where a five vowel system merges with /i/, /u/ and /a/ in unstressed syllables (Cowell (1984)), and in Bulgarian, where in a number of dialects, unstressed vowels form a three-vowel system (Scotton (1984)).

These phenomena are difficult to explain within the tongue arch model of vowel representation: even if they can be analyzed uniformly in terms of the raising of mid vowels, what remains unexplained on this model is why such phenomena should occur at all.

² That includes the recent models developed along the SPE lines, Clements (1985), Archangeli and Pulleyblank, forthcoming, Seget (1986).
³ Kenstowicz and Kisseberth (1979) treat /i/ and /e/ as i-round, to achieve a one-rule analysis of the Tunica facts. However, there are good reasons to assume that this feature does not exist, cf. Steriade (1986).

An answer to this question is possible only within a framework in which /e/ and /o/ are represented as complex segments (cf. Kaye et al. (1985), Schane (1987)).

The constriction model satisfies this requirement. On this model, vowel reduction phenomena are treated as the reduction of a complex segment in a metrically weak position (see Sagey (1986) for more discussion of the processes which reduce complex segments in metrically weak positions).

Even though most cases of vowel reduction can be analyzed in terms of a single, mid-to-high raising rule, this possibility is not always available. In this respect, consider the case of vowel reduction reported by Topping (1979) in Chamorro, also discussed by Kenstowicz and Kisseberth (1979). In Chamorro (segment inventory (Topping (1988)): p^h, p, f, b, b^h, m, m^h, t, t^h, d, d^h, ts, dz, s, s^h, n, n^h, l, l^h, ɾ, ɾ^h, k, k^h, ʒ, ʒ^h, ʔ, h, l, a, ə, u, o, c), unstressed vowels are reduced according to the following paradigm: /i/ and /e/ become /ɪ/, /u/ and /o/ become /ɒ/, and /a/ and /ə/ become /ə/. This is illustrated below:

(94)	dágo	'gem'	l degúhu	'my gem'
	péco	'chest'	l p:cohu	'my chest'
	gwáhen	'fish'	l gwáhenhu	'my fish'
	pígwəʔ	'betel nut'	l pígwə́hu	'my betel nut'

Note that in Syrian Arabic and in Bulgarian the vowel /a/ remains unaffected by the reduction process; this is what allows the tongue arch model to capture the reduction process in terms of a single (vowel raising) rule. In Chamorro, however, all vowels are affected; unless /e/ in this language is treated as a high vowel, this process cannot have a uniform interpretation in the tongue arch model.

On the constriction model, on the other hand, vowel reduction in Chamorro can be treated as a process which (in addition to laxing) deletes the Pharyngeal constriction of a vowel: this process converts /o/ and /e/ to /u/ (and later /o/) and /i/ (and later /ɪ/)

respectively, and it deletes the entire articulatory component of a low vowel. Not unreasonably, this component is replaced by a /e/. inserted by a default process.

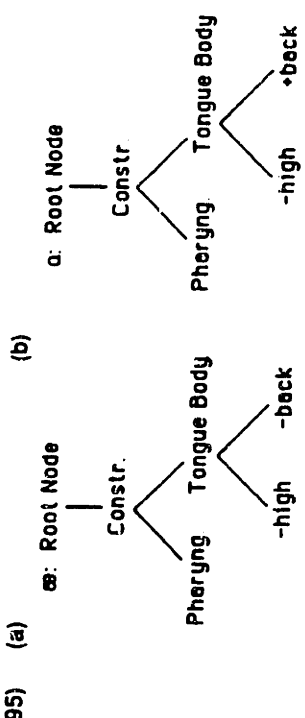
To summarize this section -- since both vowel coalescence and vowel reduction phenomena have a natural explanation when analyzed in terms of the processes affecting the Constriction Nodes of vowels, they support recognizing this node as a phonological constituent.

5.6 Vowel Representation: Residual Problems

In this section I consider some issues concerning the representation of several individual vowels which have been left out of the discussion so far. I discuss the representation of the dorsal pharyngeal vowels, in particular, the vowels /ə/ and /a/, and the representation of the front rounded vowels.

5.6.1 Dorsal Pharyngeal Vowels

The vowels which belong in this category, are /ə/ and /a/. I propose to represent them as in (95a) and (95b) respectively:



The treatment of these vowels as [-back] and [+back] respectively is well supported by their phonology: they pattern with other vowels that are characterized in terms of these features, cf. the backness harmony facts of Chamorro (Kenstowicz and Kisseberth (1979)). Since they must be characterized in terms of a feature dominated by

the Tongue Body, they have to be represented with the Tongue Body as the active Articulator. Articulatory data for American English /æ/ and /ɑ/ (Parker (1969)) confirm that indeed these vowels do not involve the tongue root constriction.

The representation of /æ/ and /ɑ/ is of particular interest, because a number of theoretical issues depend on it. For instance, given the representation in (95a), /æ/ appears to be the only vowel (so far) for which the feature [back] must be maintained in addition to the feature Palatal Site. If /æ/ could be assumed to have a palatal constriction (and /ɑ/ -- a velar one), perhaps the feature [back] could be abandoned (but see the discussion in 5.4.1).

Yet there are reasons for not considering /æ/ as Palatal: /æ/ systematically fails to trigger palatalization. Consider as an example the palatalization process in Korean (segment inventory (MacLagan (1984)): p, pʰ, pʰ, m, t, tʰ, tʰ, s, sʰ, n, l, ɕ, ɕʰ, ɕʰ, j, k, kʰ, kʰ, ŋ, h, w; vowels: i, ü, u, t, u, e, ö, o, ʌ, æ, a; plus the same series with length); palatalization is an allophonic rule which converts /s/ to /ʃ/ before palatal vowels, as shown below (data quoted from Blaszczak et al. (1987)):

(96)	ʒipap	'game'	ʃilisu	'mistake'
	ʃipsem	'thirteen'	ʃesulʃi	'washroom'
	son	'hand'	som	'sock'

The vowel /æ/ fails to trigger this process, as documented by the forms like /sæk/ 'color'.

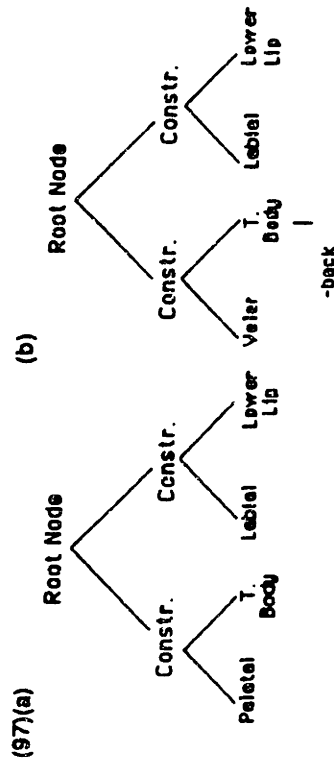
While a single example of negative evidence cannot decide whether or not a feature is absent in the representation of a segment (for more discussion of a palatalizing capacity of /æ/ see Neeld (1973)), the Korean facts make a rather good case for the

* Neeld (1973) argues for a hierarchy of palatalizing strength among front vowels. According to his hierarchy, /æ/ has the weakest palatalizing properties, but he does consider it to be a palatal segment nevertheless. However, all examples of palatalization by /æ/ which Neeld quotes (e.g., in Swedish, French), involve velars, and occur only as a historical change, not a synchronic rule. A plausible

claim that /æ/ is not palatal: the process is allophonic (note that the resulting segment, /ʃ/, is not an underlying segment of the language); generally, allophonic processes involve as triggers the entire natural class of segments.

5.8.2 Front Rounded Vowels

The constriction model allows at least two representations for the front rounded vowels; these are shown below (for convenience, I shall limit the discussion to /ü/:



A question naturally arises as to whether both options are utilized in natural languages. A relative rarity with which /ü/ triggers palatalization (cf. Neeld (1973)) suggests that the option in (97b) should be more common. On the other hand, the articulatory data on these vowels in French (Bothorel et al (1986)) and German (Martens (1984)) show /ü/ articulated with the palatal constriction. Of course, neither of these languages has a palatalization process which could help decide the underlying representation of /ü/.

Before the above question could be answered with a reasonable amount of certainty, a comparative study of the articulatory and phonological properties of these segments would have to be

explanation for the historical facts might be that velars fronted before the front /æ/ have turned into acoustically similar dorsal palatals (the stage still observed in Swedish), and subsequently, into less marked coronal palatals, as in French.

performed. At this point, such a study is unrealistic, given the fact that the articulatory data are unavailable for the majority of world's languages.

6. Representation of Speech Sounds: Consonants

In this short chapter, I consider some residual issues in the phonology of consonants. In the course of this dissertation, I have posited representations which in some cases may appear controversial and need additional justification, and in others, if successfully defended, provide additional support for the constriction model. I now discuss these cases individually.

6.1 The Representation of /k'/

I use the symbol "k'" to refer to what is known in the literature as either a "palatalized velar" (often transcribed as "k'"), or a "fronted velar", and corresponds to a sound articulated with a velar constriction with the tongue body fronted. On X-rays, this sound often appears with a closure somewhat forward of the region in which ordinary velars are articulated.

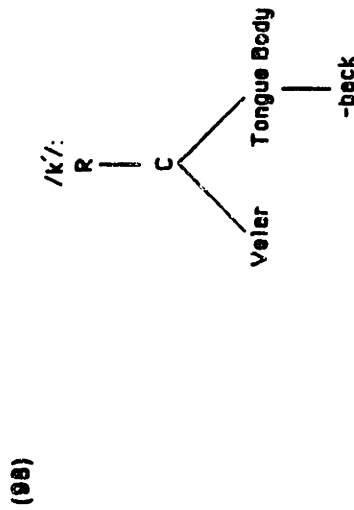
On the constriction model, it is not possible to represent /k'/ as a palatalized segment: as a secondary articulation palatalization involves a front vowel constriction. This means that a palatalized velar would necessarily have to be represented with the Tongue Body Articulator simultaneously executing two constrictions: Palatal and Velar. Following Sagay (1986) (but see the discussion in 1.4), I assume that such representations are not allowed.

On this model, there are only two possible representations for /k'/: either /k'/ involves a Tongue Body constriction at the Palatal Site, or a Tongue Body constriction at the Velar Site (the palatal stop), with the Tongue Body fronted ([l-back]). Choosing the first representation would be justified if no language ever contrasted /c/ with /k'/. Only then could the two sounds be assigned a single phonological representation, perhaps associated with slightly varying acoustic signals in different languages.

However, evidence from languages which do have palatal stops (even if only in their surface inventories) suggests that this

treatment of /k'/ is not possible. In a number of such languages, /c/ must be represented differently from /k'/, because the two sounds contrast before front vowels*. This is true of Basque (as demonstrated to me by the native speaker of the language). In Macedonian, the palatal stop may merge with /k'/ before front vowels in the speech of some persons, but in the standard pronunciation the two are kept apart (Lunt (1952), p. 12).

In view of the above, the only representation available for /k'/ within the constriction model is that of a Velar sound articulated with the Tongue Body modified by the feature [-back], as shown in (58):



Below I argue that this representation is consistent with the behavior of /k'/ in phonological processes.

/k'/ systematically fails to pattern with the palatal or palatalized segments. In this respect, consider the following facts from Polish, language which has a wide range of palatalized

* Incidentally, this fact constitutes a problem for the articulator theory of Sogey (1966): since it can represent the contrasts among the dorsal sounds in terms of the features [back], [high] and [flow] only, it is not capable of representing the contrast between /c/ and /k'/. The only recourse for this theory is to assume that palatal stops are non-strident coronals (provided that the feature [coronal] is redefined to include the front part of the dorsum). However, this treatment of palatal stops is not justified by their patterning in phonological processes, as I demonstrate below.

segments (e.g., t', s', d', z' (phonetically realized as distributed coronal palatals; see 3.2.2), p', t', b', l', etc.), which exist in the underlying inventory of the language, but may also be created by the phonological processes.

As is well known (cf. Rubach (1984)), suffixes which begin with a front vowel in Polish (/i/ or /e/) can be either cyclic, in which case they trigger palatalization, or non-cyclic, in which case they do not. The cyclic suffixes induce the following changes in the stem-final consonants: labials and dentals are palatalized (p --> p', b --> b', t --> t' (followed by the change to /c'/), while velars turn into coronal palatals (k --> ž, g --> ż, x --> ś). This is illustrated below:

(99)(a)	tu ^h + i + t' --> tu ^h i ^c	'to rob'
	red + i + t' --> redzi ^c	'to advise'
	krok + i + t' --> kroci ^c	'to march'
(b)	x ^h top + isk + o --> x ^h top'isko	'peasant, augm.'
	ko ^h t + isk + o --> ko ^h ci ^c sko	'cat, augm.'
	no ^h g + isk + o --> no ^h ci ^c sko	'leg, augm.'

I analyze the process illustrated above along the lines proposed in Gorecka (1989): the Palatalization Rule spreads the Palatal/Tongue Body constriction of /i/ onto the Root Node of a preceding consonant. The immediate output of this process is a palatalized segment, which in the case of labials and dentals remains unaltered, as these are also the underlying segments in Polish. The effect the palatalization process has on velars is predicted by the constraints on possible representations which I assume in this thesis: while a Palatal/Tongue Body constriction may spread onto a Velar segment at the stage when it lacks the Articulator specification (possible only in languages which do not have a k : k' contrast), such a representation cannot surface as a fully specified, doubly articulated segment, and therefore, must be reanalyzed as a single palatal (or the palatalization effect can be nullified, but obviously, this is not the course of events in Polish).

When followed by a non-cyclic suffix which begins with a front vowel, stem-final consonants are unaffected if they are labials or dentals; velars, however (with the exception of /x/) are fronted. This is shown below:

(100)(a)	żab + i ---> żabt	'frogs'
	kot + i ---> kott	'cats'
(b)	nog + i ---> nogi	'legs'
	krok + i ---> krok'i	'steps'

The effect front vowels in Polish have on velars would be difficult (if not impossible) to explain if /k'/ were to be treated as a palatalized velar. While the data in (99), could plausibly be treated in terms of Structure Preservation (after all, Polish does not have an underlying /k'/), the data in (100) are more of a problem. Here velars are "palatalized" and nothing else is.

This fact is not a problem for the treatment of /k'/ adopted here. In (100) velars are fronted (for the analysis of the mechanism behind this process see 4.3). The reason why no other segment in the language undergoes this rule is simple: no other segment can be a target of the process which spreads the Tongue Body Articulator in a feature-filling fashion.

There are many other examples of phonological processes in which /k'/ fails to pattern with the palatalized consonants. In Polish, again, it fails to act like a palatalized segment in the process of Palatalization Spread discussed earlier in 4.1.1. This rule palatalizes dental sibilants when they are followed by a palatalized segment: either /p'/, /t'/, or /l'/, etc. This is not a cyclic process, as it applies across the board (except when the prefix boundary intervenes between the trigger and the target; for an explanation as to why this should be the case see Czaykowska-Higgins (1988)). Yet /k'/ fails to trigger it. This is illustrated below:

* I have no explanation for this.

(101)(a)	ściana	'wall'	śpiew	'singing'
	kość	'bone'	ślept	'blind'
	źle	'wrong'	śpi	'sleeps'
(b)	faszki	'favers'	pesk'em	'belt, instr.'
	zgętk	'noise'	dżęzi	'splinters'

Another example along the same lines comes from Bulgarian, where palatalized segments are exceptionlessly depalatalized before front vowels cf. /kon'o/kone/ 'horse' (this phenomenon has been discussed earlier in 3.3.2). In the same environment velars are fronted, cf. /b'tag'v/ 'sweet'.

These facts are easily explained under the assumption that /k/ is a fronted velar: it cannot spread the palatal constriction in the Polish case, and it cannot lose it in Bulgarian, because it does not have it. While the above phenomena can also be handled on the assumption that /k/ is a palatalized consonant, say, by invoking rule ordering, the point that remains is that /k/ never patterns like a palatalized segment. This generalization is just an accident on the theory that /k/ is a palatalized velar.

6.2 The Representation of /c/

In this section I argue for representing /c/, the so called "palatal stop" (as well as any sound from the family of palatals: /tʃ/, /tʃʰ/) as a simple segment with a Tongue Body constriction at the Palatal Site. Since I have already shown in 6.1 that this sound cannot be reduced to /k'/ (a fronted velar), all that remains to be shown is that it cannot be represented as a coronal segment with [-anterior] specification, distinguished from /tʃ/ in terms of stridency.

Consider again vowel hardening process in Kinyarwanda, discussed in 3.4.2. In this process, a vowel fuses with a preceding consonant when it is followed by another vowel (the analysis of this phenomenon in terms of a complex segment formation follows Sagey (1986)). If it is a front vowel, it gives rise to a palatal stop component in the resulting complex segment. Since the resulting

complex segment may contain an unquestionably coronal component, e.g., ku-se-a --> kus^aa 'to grind', ku-ri-a --> kur^aa 'to eat', then, given Sagey's (1986) constraint against complex segments mentioning the same articulator twice, it follows that the /c/ (/ɟ/) component in these segments cannot be analyzed as coronal.

Given the characterization of /c/, /ɟ/, /n/, etc. as the dorsal palatals, one would expect that they can be determined as dorsal by the same criterion by which they have been determined as non-coronal, namely, they are predicted not to occur as component articulations in complex segments that have a velar/dorsal component. The testing ground is fairly limited in Kinyarwanda -- according to Kimenyi (1979) the only palatal segment that occurs in the environment in which it could potentially merge with a demoted velar vowel is /n/. However, for this particular segment, the above prediction appears to be correct: the palatal nasal is always deleted in such environments*:

- (102) ku + mep + w + e ---> kumen^ae ('to be known')
 ku + seep + w + e ---> guseen^ae ('to be destroyed')
 ku + no + e ---> kun^ae ('to drink')

The conclusion that /c/ cannot be treated as a coronal, and must be treated as a dorsal segment instead, and the conclusion that it must be represented as distinct from /k/ combine together into an argument against the articulator model of phonological representation of Sagey (1986), since this model cannot assign distinct representations to /k/ and /c/ that could explain the phonological behavior of these sounds.

3.3 Uvulars as Complex Segments

* Kimenyi mentions one class of exceptions to this generalization: apparently, the palatal nasal is not deleted when merged with the velar vowel if it is derived via a mutation rule. This rule affects consonants before the causative marker /-j/. The only explanation for this fact I can think of is that perhaps in these constructions, a palatal/velar nasal is reanalyzed as a palatal/coronal.

McCarthy (1989) proposes to treat uvulars as complex segments which are both velar and pharyngeal, and presents a number of arguments for this view.

First, he observes that uvulars pattern with both velars and pharyngeals in determining the distribution of segments in trilateral roots; as amply shown by McCarthy (1979, 1981, 1988, 1989), Arabic displays phonological processes which are best understood under the assumption that in the underlying representation, consonants and vowels of Arabic occupy separate melodic tiers. This assumption plays a key role in explaining the cooccurrence restrictions on consonants in trilateral verbal roots, in particular, the fact that these restrictions are more severe among the consonants which are adjacent within a trilateral root (despite the fact that they may be separated by vowels in surface forms) than among the non-adjacent ones.

McCarthy (1989) shows that in trilateral roots, uvulars fail to cooccur with either velar or pharyngeal consonants. Given this fact and the generalization that cooccurrence restrictions in Arabic prohibit the adjacency of segments which are articulatorily similar, it follows that uvulars must be perceived as articulatorily similar to both velars and pharyngeals. McCarthy's conclusion is that uvulars share articulatory features with both velars and pharyngeals, and that in fact they are complex segments which involve the two points of articulation.

McCarthy's insight, when incorporated into the framework of the constriction model, translates into an analysis of uvulars as segments involving a Velar/Tongue Body and a Pharyngeal/Tongue Root constriction.

This characterization of uvulars has proven useful in the analysis of Arabic ablaout in 3.5.2: it made it possible to explain why these segments pattern with either velars, causing the ablaouting vowel to surface as /u/, or as pharyngeals, changing the ablaouting vowel to /a/. (A rather similar ablaout pattern has been discovered

(not surprisingly) in Palestinian Arabic, by Younes (1982), also quoted by McCarthy).

7. Phonological Processes

This chapter is concerned with the constraints on phonological processes which are not feature-particular, but appear to be structurally determined instead. I attempt to derive some of these constraints from the general properties of the constriction model. In cases where this model appears to overgenerate, I introduce constraints which limit its power.

7.1 Some Predictions about the Processes Which Affect Non-adjacent Segments

In this section, I propose to derive the locality conditions on the assimilatory processes from the position the spreading features occupy in the segmental tree: I show that non-local spreading of features is possible only when intervening segments do not provide the "landing site" (are not suitable hosts) for the feature that spreads.

In terms of the locality conditions which they observe, phonological processes can be superficially divided into two categories: those which may spread features while skipping (specified) segments, and those which may never skip a specified segment. The first category includes backness, height, tenseness harmonies among vowels, and retroflexion and sibilant harmonies among the consonants. The second category consists of all point of articulation assimilations, palatalization*, velarization, voicing or stricture assimilations, etc.

Putting aside the retroflexion and sibilant harmonies for the moment*, it becomes immediately obvious what the processes in the first group have in common: they all spread Articulator-dominated features. Since this generalization does not appear to be a result of

* With one known exception, namely, palatalization of /s/ in Karak.

* Since it is not obvious what features are spread in these processes.

an accident, a systematic explanation for the phonological behavior of the Articulator-dominated features should be available.

The explanation which I propose derives the special status of these features from their position within the feature hierarchy. While not ruling out a possibility that a phonological process may make reference to prosodic information, and therefore require adjacency of the segments involved, I want to suggest that all else being equal, processes that "skip" segments, spread features for which the "skipped" segments cannot provide a "landing site", in other words -- a mother node. This proposal predicts that processes which spread the Constriction Node or any feature directly dominated by the Root Node may never skip a segment, unless the segment can be argued to be completely unspecified (a possible example of this might be consonant assimilation in Koley-I, discussed by Archangeli (1986)). Similarly, processes spreading Articulator/Site features are predicted to observe strict adjacency, unless intervening segments can be argued to lack the Constriction Node.

This proposal explains why the Articulator-dominated features have such a special status in phonology: since they can spread only onto their mother Articulators, they can skip segments which lack such specifications. Thus, the features dominated by the Tongue Body Articulator ([high], [back]) are allowed to skip all intervening segments which lack the Tongue Body specification. This is indeed what we observe in the case of [backness] or [height] harmonies: they propagate across any consonant. Of course, they skip ordinary velar consonants as well, despite the fact they are dorsal segments, but this fact has a simple explanation, consistent with what has been said about velars earlier: since their Articulator specification is universally predictable, it is assumed not to be present in their underlying representation.

The "landing site" view of the locality conditions on rules not only explains the special behavior of the [high] and [back] features, it also predicts that segment skipping assimilations may involve only

Articulator-dominated features (again, aside from a few narrowly defined cases where the skipped segments are severely underspecified and lack either the Constriction or the Root Node).

With this in mind, let us now turn to the harmony processes among consonants. While such processes are far less common than the harmonies affecting vowels, they do occur nevertheless. Several examples commonly quoted in the literature include retroflexion (e.g., n-retroflexion in Sanskrit) and sibilant harmonies (e.g., in Chumash, Navajo, Kinyarwanda, etc.). The analyses of these phenomena in the recent literature do not support the "landing site" view of the locality conditions, as they attribute the harmonies variously to the spread of the Coronal Articulator (cf. Schein and Steriade (1986)), or the feature [anterior], (cf. Poser (1982)). Below, I consider a possibility of reanalyzing the above cases of consonantal harmonies in terms of the Articulator-dominated features.

In Sanskrit (consonant inventory (Whitney (1889)): p, m, t, n, s, ʈ, ɖ, ʑ, ɽ, ɕ, ʃ, ɟ, k, ɳ, /n/ became retroflex ɳ after a retroflex continuant (either /sɖ/ or /rɖ/), with any amount of phonological material intervening, as long as none of the segments were coronal. Another condition on the rule, which I do not discuss beyond this statement, was that /n/ had to be followed by a liquid sonorant (see Schein and Steriade (1986) for the discussion of this condition). Here are several examples of the retroflexion harmony:

(103)(a)	pur-e.ɳə-	'fill'	vs.	kʂvəd-e.ɳə-	'hum'
	vrk-ɳə-	'cut up'		mɽd-ɳə-	'be graceful'

The analysis of n-retroflexion proposed by Schein and Steriade (1986), also followed by Sagey (1986), attributes the process to a rule which spreads the Coronal Node which dominates the features [-anterior] and [-distributed]. The main reason for appealing to the Articulator node rather than just one of the features below it, is that such an analysis explains the blocking of the rule by all coronal segments in the language.

Obviously, from the point of view of the proposal I am introducing in this section, such an account of Sanskrit n-retroflexion is not possible. The only situation in which an Articulator node could spread across a segment under this proposal, would be if a segment lacked the Constriction Mode. This is clearly not the case in Sanskrit, where any non-coronal segment may intervene between the trigger and the target in n-retroflexion. The only analysis available under this proposal is in terms of the feature [distributed]: among all the possible candidates, this feature is the only one that can propagate across non-coronal segmentalists.

Given the analysis of n-retroflexion in terms of [distributed], how is the coronal blockage to be accounted for? After all, the proposal I am introducing makes no statements about the transparency or opacity of segments. By this proposal, the feature [distributed] should be allowed to spread on all the coronals.

Yet the blocking effect can have an independent explanation: suppose that n-retroflexion applied in Sanskrit after all the coronals (other than /n/) have received their redundant specifications for [distributed]: in such a case, blocking would be caused by the feature [distributed].

While I know of no independent evidence from Sanskrit for the above analysis, there are good reasons for believing that it is nevertheless correct: the analysis in terms of the Articulator spreading predicts that there should exist cases of long distance spreading of the Articulators, not only among the sounds that are executed with the same articulator (note that under the Articulator spreading analysis of n-retroflexion, the Coronal Articulator spreads to dislodge the Coronal Articulator), but also among the sounds executed with different Articulators. I do not know of a single example of such a phenomenon.

Next, let us consider briefly an example of a sibilant harmony, such as the one which occurs in Chumash. Since I discuss this

phenomenon in some detail in the next section, I refer the reader to consult the data there.

In Chumash (segment inventory (Ruhlen (1975)): p, m, p^h, m², t, ts, s, n, l, t^h, ts^h, s^h, n², l², t², s², ts², ʔ, ʔ², ʕ, ʕ^h, ʕ², ʕ̌, ʕ̌^h, k, k^h, k², q, q^h, quɫ, x, x², ʔ, h, l, e, t, u, o, a), all sibilants in a word must belong to either a /ʕ/, /ʕ̌/ set, or to a /s/, /ts/ set. Alternations reveal that the underlying quality of a sibilant is subordinated to the quality of the rightmost sibilant in the word. Since the sounds in the /ʕ/, /ʕ̌/ series are laminal, and the sounds in the /s/, /ts/ series are apical, the harmony rule effects two changes simultaneously: it changes the constriction location of a segment (Palatal <--> Anterior), and it changes its specification for [distributed].

Poser (1992) considers a possibility that the harmonic feature in Chumash is [anterior]. Clearly, such an account cannot be accommodated under the proposal which derives the locality conditions on assimilations from the position of the assimilatory feature in the segmental tree; the only possible candidate for the harmonic feature under this proposal is the feature [distributed], which is dominated by the Tongue Blade Articulator in the segmental tree (recall that this feature may be relevant only in the phonology of the coronal segments).

There are at least two arguments for positing [distributed] (and not the Sites) as the harmonic feature in Chumash. First, any vowel can intervene between the trigger and the target, including the palatal vowels (see the data in 7.2), without creating the blocking effect. Second (this argument is external to Chumash), of all recorded cases of sibilant harmonies (cf. Bhat (1978)), each and every one involves the change of the value for [distributed], in addition to any other change. No language in which the Anterior and the Palatal coronals agree in the value of this feature displays a sibilant harmony.

On the basis of the preceding discussion, it is possible to conclude that the facts of Sanskrit and Chumash, as well as all

generalizations about consonantal harmonies, support the proposal which derives the locality conditions in assimilations from the position of the assimilatory feature within the segmental tree.

Before leaving this section, I would like to consider the troublesome case of palatalization in Karok (segment inventory (Bright (1957)): p, f, β, m, θ, t, s, n, ʤ, ʃ, k, x, ʔ, h, l, a, u, i, e, ɛ, i:, o:, u:). As mentioned earlier, palatalization in this language, triggered by /i/, /e/ and /j/, can skip any consonant to reach /s/.

Examples:

- (104) ʔi:nfárup 'threshold of Indian house'
 ʔf:fáip 'to grow'
 ikzfrípáip 'to start to run'
 ʔikšəh 'laugh'

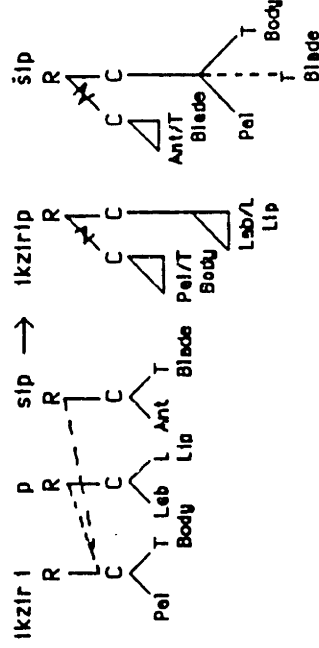
Since I propose to treat palatalization as a process which spreads the Palatal/Tongue Body constriction of a vowel onto the Root Node of a consonant (cf. Gorecka (1989)), I predict that such a process must be strictly local. Therefore, its ability to skip consonants in Karok presents a problem for the "landing site" theory of the locality conditions.

Yet despite this appearance, the palatalization process in Karok can be analyzed in a manner consistent with this theory. It is possible to posit palatalization spread* in Karok, not unlike the process which I have motivated for Polish in chapter 4. The only difference between the two cases would be that in Karok, the Palatal constriction would be delinked from any consonant that is not /s/. The /ʃ/ would be assumed to surface eventually with a copy of the Palatal constriction independent of the trigger vowel, to satisfy the constraint which prohibits the association lines from crossing (Goldsmith (1976)), and also, to account for the fact that the Palatal constrictions of the target and the trigger in this palatalization process surface with different articulators (the

* This analysis has been suggested to me by Michael Kenstowicz.

Tongue Blade and the Tongue Body). On such an analysis, the derivation of the surface form such as /ikzfrípáip/ 'to start to run' would proceed as follows:

(105)



As a final comment to this section, I would like to point out the following: while the "landing site" theory of the locality conditions on assimilations is conceptually independent of the constriction model, and it can be applied in the phonological analysis under any model of segment representation, of the presently available proposals, only the constriction model provides the hierarchy of features which can produce the correct results under this theory. Consider, for example, the articulator model of Sagay (1986): using the same idea, it is possible to rule out on that model long distance Articulator spreading: since Articulators are dominated directly by the Place Node, no segment that already has a Place Node may be skipped by such a rule. However, given that the feature [anterior] is a dependent of the Coronal Articulator on this model, and given the prediction that Articulator-dominated features can skip segments not specified for their mother Articulators, this model predicts the existence of harmonies spreading the feature [anterior] only. This prediction is not borne out by the available data (see the discussion above).

7.2 A Problem for the Constriction Model and Possible Solutions

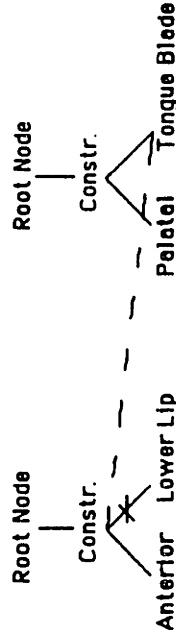
In the preceding chapters, I have presented a number of arguments for including the Site and the Articulator features in the phonological representation, and I have proposed a hierarchy of these features within a phonological segment, capable of explaining certain aspects of their behavior in phonological processes. Still, the constriction model, if left unqualified, allows for phonological processes which, to my knowledge, do not occur.

Given the range of phonological processes observed in natural languages, an adequate model of phonological representation must allow independent spreading of Articulators, Sites, and the features which are dominated by the Articulators ([back], [high], [distributed], etc.), as demonstrated extensively throughout this thesis. Obviously, the feature hierarchy proposed in chapter 4 delivers this result. At the same time however, there are reasons for wanting to constrain that freedom.

As it stands, the constriction model allows all features to spread in cumulative fashion: a Constriction Node may spread onto the Root Node of a segment, even if this node already dominates a Constriction Node; an Articulator or a Site feature can spread onto the Constriction Node, even if this node is already fully specified in terms of both the Articulator and the Site; finally, an Articulator-dominated feature may spread onto an Articulator that bears an opposite specification of the same feature.

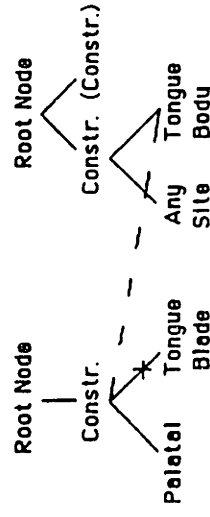
However, some of the processes which this model predicts to be possible, do not occur. Here are some examples: spreading of an Articulator feature in cumulative fashion (with subsequent deletion of the original Articulator specification) should allow an assimilation of /l/ to /s/ (or /θ/) before, say, /t/; this is illustrated below:

(106)



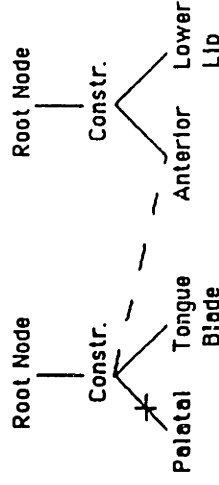
Or it should allow a conversion of a coronal palatal to a dorsal palatal before vowels /i/, /u/, /e/, and /o/, as demonstrated below:

(107)



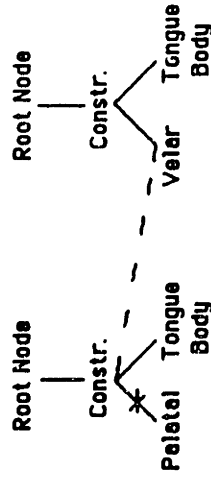
If Sites were allowed to spread cumulatively, the following processes should occur: /ʃ/ should be able to turn into /s/ before /l/, as shown below:

(108)



Or we should be able to find /i/ commonly turning into /u/ before a velar:

(109)



None of the processes illustrated in (106) through (109) occur commonly or occur at all. This gap does not appear to be accidental, which means that a systematic explanation is in order.

One way of blocking the derivations in (106-109) would be to introduce a constraint which would prevent cumulative spreading of features. Unfortunately, such a constraint is too powerful in that it blocks some of the most common processes, such as palatalization, velarization, labialization, in fact all the processes which introduce secondary articulations. Since all these processes spread the Constriction Node(s), it is reasonable to conclude that this node may spread cumulatively.

Putting aside Articulator-dominated features for the moment, it appears that only Sites and Articulators may not spread cumulatively; the Constriction Node can. Before I attempt to account for this fact, I want to point to a fundamental difference between the processes which spread Sites and Articulators on the one hand, and the Constriction Node on the other hand: while the latter processes may result in possible speech sounds, no process which spreads either Site or an Articulator cumulatively can produce an intermediate output that would map directly onto a grammatical representation: there are no possible speech sounds which can be characterized as involving one Articulator executing a single (!) constriction at two Sites, or two Articulators executing a single constriction at one Site.

Suppose now that phonological processes could not apply in ways that would result in ungrammatical representations -- if this indeed were the case, nothing would need to be said about the manner in which phonological features could spread; the derivations in (106-109) would be automatically ruled out, because their first stage would always be an ungrammatical representation.

The above proposal, while somewhat radical at first sight, is not really that far apart from the common sense intuitions that most phonologists share. To my knowledge, no serious phonological analysis has been offered that posited impossible speech sounds in the underlying inventory of a language. And even if sometimes derivations are proposed that proceed through an "ungrammatical intermediate stage", I am not aware of any analysis that would actually take advantage of the impossible feature combinations and derive phonological effects from them.

At this point, a question could be reasonably asked why phonological processes could not apply in such a way so as to accomplish the spreading of Site/Articulator with a simultaneous delinking of an original Site/Articulator specification (recall that this is precisely the kind of derivation I have shown in each of the cases in (106-109) in order to make them look at all sensible). Given a possibility of such derivations, the system would still be able to overgenerate. Therefore, in order for the above proposal to work in the manner intended, spread-and-delink derivations would have to be disallowed.

Simultaneous spread-and-delink derivations could be blocked easily, if phonological processes were not allowed to accomplish more than one change at a time, in other words, if they were assumed to be completely atomic. In such a case, delinking procedure would have to be viewed as a phonological process separate from spreading. Again, this is not an unreasonable assumption in the present day phonology; after all, one of the main reasons for positing segmental trees has been to allow the spreading of multiple features by single (atomic) rules.

Still on the same topic -- in the discussion of palatalization phenomena in Goretka (1989) I conclude that at least among these phenomena, there are no examples of spread-and-delink rules. This is based on the observation that segments which are derived as a result of palatalization (complex segments with a front vowel articulation) are never simplified, unless there exist conditions in the language which trigger such a process.

If this generalization should turn out to be true of other phonological processes as well, then the derivations in (106-109) would no longer be an embarrassment to the constriction model; they would be ruled out on independent grounds.

In this spirit, let us now consider processes spreading Articulator-dominated features ([high], [back], [distributed], etc.). While early analyses of such processes have relied crucially on the existence of spread-and-delink rules, under the assumptions of underspecification theory (Archangeli (1984)) many harmony rules have been reanalyzed as feature-filling (cf. the articles in Phonology, vol. 5, and numerous references there). Even so, there still exist phenomena which, at least on the face of things, appear to require a spread-and-delink analysis. Sibilant harmony in Chumash, analyzed by Poser (1982), Steriade (1987), may be considered a classical example of such a phenomenon. Below, I propose an analysis of the Chumash facts, which does not need to appeal to the spread-and-delink rules.

In Chumash, all sibilants in a word must agree with the rightmost one in the value for [distributed]. The interpretation of Chumash harmony in terms of [distributed] is my own (see the discussion in 7.1); Poser (1982) and Steriade (1987) consider a possibility that the spreading feature is [anterior]. My reinterpretation is based on the information that palatals are laminal and alveolars are apical in Chumash (cf. Bhat (1978)). Experience with other processes, similar to this one, shows that sibilant harmonies occur only when alveolars and palatals have opposite specification for [distributed]. In 7.1, I have argued that the

only possible interpretation of such harmonies is in terms of the feature [distributed], despite the fact that other features are affected along the way.

- (110)(a) k + sunon + us --> ksunonus 'I obey him'
 (b) k + sunon + š --> ksunontš 'I am obedient'

Poser shows that the harmony can change both values of [distributed]; causative suffix whose isolation form is /su/, appears as /šu/ in words in which the last sibilant is /š/, and the dual subject marker, whose isolation form is /lš/, appears as /ls/ in words with the last sibilant /s/. Here are the examples:

- (111)(a) su + wəyan --> suwəyan 'cause to hang'
 (b) k + su + šoyIn --> kšušoyIn 'I darken it'
 (112)(a) p + lš + al + nan' --> plšanan' 'don't you two go'
 (b) s + lš + tlišl + yep + us --> slstlptlɛpus 'they two show him'

On the basis of these and similar examples Poser argues that the sibilant harmony in Chumash is feature changing. Given the appearance of the data in (111-112), one may be lead to such a conclusion easily. However, despite this appearance, it is possible to analyze the facts of Chumash without assuming that one value of [distributed] spreads and delinks the other value.

Even though Chumash has both apical and laminal sounds in its inventory, the apical/laminal distinction does not need to support a phonemic contrast: laminals (/š/, /tš/, etc.) are always Palatal and apicals (/s/, /ts/, etc.) are always Anterior. This means that the distribution of both values for [distributed] is predictable in Chumash, and therefore, neither specification for [distributed] need to be present underlyingly in this language.

On this assumption, the harmony process in Chumash may be viewed as spreading both values of [distributed] to segments that lack any specification for this feature. While the spreading process itself is not feature changing*, the effects of the harmony are: palatal segments which receive [-distributed] specification must ultimately be converted to anterior segments, and alveolars which receive [+distributed], must be converted to palatals, as the harmony is structure-preserving.

The support for the present analysis of Chumash harmony comes from the following facts (also reported by Poser): there is a process in Chumash which converts /s/ to /š/ before /l/ /l/, /n/, in derived environments. The derived /š/ does not undergo the sibilant harmony, as shown in (113):

(113) s + tɬ + jəp + us --> štɬjəpus 'he tells him'

It is not the simple matter of ordering the rules*, as the derived /š/ does spread its value for [distributed]:

(114) s + ts + tɬ? --> štsɬtɬ?+ 'he finds it'

The most natural explanation for these facts is that following a rule which specifies the value for [distributed] in a segment (made evident by the fact that this value can be phonologically active), the

* In order for the harmony in Chumash to apply in the feature-filling fashion, it is necessary that the redundant specification for [distributed] not be assigned to all morphemes simultaneously. While it is not uncommon for the harmony processes to subordinate all targets to the most prominent trigger in the word; it can be either a stressed vowel, or the rightmost (leftmost) vowel, etc., it is not clear how a rule can pick out the rightmost coronal. As pointed out to me by Donce Steriade, phonological processes do not apply to the rightmost sibilants, obstruents, etc. At this point I do not have a proposal that would explain this aspect of my analysis.

* Although this is precisely the position taken by Poser, Poser suggests the possibility that the harmony process applies in two stages: first, both values of the harmonic feature are delinked; second the harmonic feature spreads from the rightmost trigger. Since there are two distinct processes, another phonological process is allowed to intervene. The change from š to a palatal before llɬ is thought to occur between delinking and spreading of the harmonic feature. While this solution does account for the data, it lacks the explanatory persuasiveness -- as it is not clear why delinking would apply in the first place.

segment is no longer a possible host for the harmonic feature, nor can it be transparent to its spreading, much in agreement with the current assumptions about the nature of opaque segments.

Under the above analysis, the facts of Chumash are not only consistent with the theory that spread-and-delink rules are unnecessary, but far more than that, they provide a strong argument against positing such rules.

Whether or not spread-and-delink rules can be completely abandoned in phonology, cannot be decided on the basis of one or even several examples. The ultimate fate of such rules may depend on what the final shape of underspecification theory will be, as the questions about the way the rules apply are directly determined by what phonological representations they apply to. Richly specified representations are more likely to require rules changing feature specifications than the representations which are severely underspecified.

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