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Feature Geometry and Dependency: A Review

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Abstract. A fundamental problem in phonological theory is the fact that processes often operate on consistent subsets of the distinctive features within a segment, like the features that characterize place of articulation. Recent research has responded to this problem by proposing a hierarchical organization of the features into functionally related classes, grouped under nodes of a tree structure. This 'geometry' resembles earlier theories that accomplish the same thing with multivalued features. This article reviews and expands the evidence for feature geometry. Within the segment, it is argued, the major dichotomy is between a Laryngeal node and a Place node. The manners of articulation – sonority, consonantality, nasality, and continuance – inhere in the segment itself rather than any of its subsidiary parts. Within the Place node, the division is into major articulators, each with its own subordinate features. Evidence is drawn from processes of assimilation and debuccalization and from the assimilatory and dissimilatory effects of the Obligatory Contour Principle.

1. Introduction

The goal of phonology is the construction of a theory in which cross-linguistically common and well-established processes emerge from very simple combinations of the descriptive parameters of the model. During the last 10 years or so, phonological theory has made great progress toward this goal by adhering to two fundamental methodological premises. The first is that primary emphasis should be placed on studying phonological representations rather than rules. Simply put, if the representations are right, then the rules will follow. The entire theory or research program known as nonlinear phonology is based almost entirely on this idea. The second premise is that modular theories are generally more constrained than homogeneous ones. For this reason, nonlinear phonological theory is segregated into distinct but interacting subcomponents dealing with stress, syllabification, and segmental phonology.

One module of the theory that has emerged quite recently is called feature geometry (although it is not a geometry per se). This theory primarily addresses one important problem: how are the different distinctive features classified by phonological processes? The basic answer is unsurprising: they are classified primarily (but not exclusively) according to articulatory function. The representations postulated by feature geometry simultaneously provide a plausible interface between phonology and articulation and describe common phonological phenomena with a simple, almost minimal set of operations. The representations establish a classification of the features based on a hierarchical structure – the 'geometry' of the title.

In this article I provide an introduction to and an overview of the theory of feature geometry. I focus first on the major results and then turn to particular questions of featural organization. Along the way we necessarily encounter other issues, especially the character of segmental operations in nonlinear phonology. I conclude by briefly addressing the important question of the relation between this formal phonological theory and its phonetic counterparts. In my discussion, I draw heavily on a number of recent publications on feature geometry, particularly the contributions by Clements [1985] and Sagey [1986].

2. The Gross Architecture of the Features

2.1 Background and Initial Results

In the theory of segmental representation presented by Chomsky and Halle [1968] and their precursors, each segment is decomposed into a simple list of binary-valued distinctive features, as in the word *tee* in (1):

(1)

$$
\begin{array}{c} \text{t} \\ \begin{bmatrix} -\text{son} \\ +\text{cons} \\ -\text{syll} \\ +\text{cor} \\ +\text{ant} \\ -\text{high} \\ -\text{low} \\ -\text{back} \\ -\text{cont} \\ -\text{nas} \\ -\text{lat} \\ \text{etc.} \end{bmatrix} \end{array}
\qquad
\begin{array}{c} \text{i} \\ \begin{bmatrix} +\text{son} \\ -\text{cons} \\ +\text{syll} \\ -\text{cor} \\ -\text{ant} \\ +\text{high} \\ -\text{low} \\ -\text{back} \\ +\text{cont} \\ -\text{nas} \\ -\text{lat} \\ \text{etc.} \end{bmatrix} \end{array}
$$

There is no classification of the features inherent to the theory. Traditionally, however, it has been recognized that the various distinctions fall naturally into groups: the major class features [sonorant], [consonantal], and [syllabic]; the place features [coronal], [anterior], and the tongue-body features [high], [low], and [back], and the manner features [continuant], [nasal], and [lateral].

This grouping of features is not based so much on any similarity of articulatory or acoustic correlates as on the functional coherence of the feature groupings in phonological rule systems. The place features in particular act as a set in widely attested phonological processes. For example, in very many languages we find a rule that assimilates nasals in place of articulation to following consonants: *N+p* → *mp, N+t* → *nt, N+k* → *ŋk*. This rule must manipulate a set of at least three different features, [coronal], [anterior], and [back], formalized as in (2):

(2)

$$[+\text{nas}] \rightarrow \begin{bmatrix}\alpha\text{cor}\\ \beta\text{ant}\\ \gamma\text{back}\end{bmatrix} / \_\_ \begin{bmatrix}\alpha\text{cor}\\ \beta\text{ant}\\ \gamma\text{back}\end{bmatrix} \quad \text{where } \alpha, \beta, \gamma \text{ are variables over + and −.}$$

The problem is that, absent some theory of how distinctive features are classified, this common process is predicted to be no more likely than an impossible one that assimilates any arbitrary set of three features, like [coronal], [nasal], and [sonorant].

Place assimilation, then, has no privileged status in this theory because of the lack of a built-in featural taxonomy. There is, moreover, another problem, first noted by Bach [1968], that is equally serious: assimilation itself also has no privileged status. A slight change in rule (2), well within the formal boundaries permitted by the theory, produces the impossible rule (3):

(3)

$$[+\text{nas}] \rightarrow \begin{bmatrix}\alpha\text{back}\\ \beta\text{cor}\\ \gamma\text{ant}\end{bmatrix} / \_\_ \begin{bmatrix}\alpha\text{cor}\\ \beta\text{ant}\\ \gamma\text{back}\end{bmatrix}$$

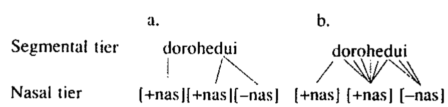
This rule uses the mechanism for assimilation, variables over + and –, in a nonassimilatory way.

Why, from a formal standpoint, is assimilation so common? The answer to this comes from the fundamental ideas of nonlinear phonology laid out in Goldsmith [1976]. Assimilation is the extension or spreading of the assimilating feature over a wider domain. Distinctive features are segregated onto different planes of phonological representation, called tiers. The coordination of gestures on these tiers is accomplished by association lines, links between the different levels. Association lines are subject to a single well-formedness constraint, the Line-Crossing Prohibition:

(4)
Line-Crossing Prohibition
No association lines between the same two autosegmental tiers may cross.

An example in which the Line-Crossing Prohibition assumes particular importance is the process of nasal harmony (assimilation) in Guaraní [Goldsmith 1976], somewhat simplified here. Guaraní has a rule which spreads or assimilates the feature [nasal] bidirectionally. This spreading stops just at the point where it would, if continued, violate the Prohibition. So the underlying representation in (5a) becomes the derived representation in (5b):

(5)



The spreading rule itself, then, can be unrestricted; the limitations on its scope follow from the universal Line-Crossing Prohibition.

The idea that assimilation is spreading of an association line resolves the problem raised by (3). Assimilation is a common process because it is accomplished by an elementary operation of the theory – addition of an association line. A rule like (3) is far more complex to state than any true assimilation. Furthermore, the Line-Crossing Prohibition imposes a particular locality requirement on assimilatory processes: assimilation across a segment already specified for the assimilating feature is impossible. Thus, although action at a distance is permitted, its effects are constrained in this way.

We are now in a position to turn to the basic motivation for feature geometry, the naturalness of place assimilation rules like (2). Since we have essentially resolved the problem of assimilation, the issue now is why the place features form a coherent subset that appears frequently in phonological rules but other arbitrary subsets of the features do not. There are three possible moves we could make at this point:

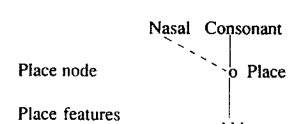
(1) Establish a set of postulates for natural subgroupings of the features. This nonrepresentational solution would work, since it essentially stipulates the desired result, but it is unlikely to have interesting consequences beyond the question at hand.

(2) Characterize the place distinctions by a single *n*-ary valued feature rather than a set of binary features. In that case, place assimilation is simply spreading of the feature [Place]. I will address this proposal in section 2.4 of this article.

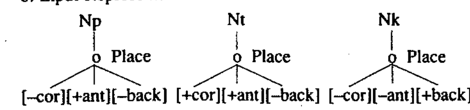
(3) Represent the features hierarchically, with the place features as daughters of a single abstract node, Place. Place assimilation, then, is spreading of the Place node rather than the individual features characterizing place distinctions.

This last proposal is the basis of feature geometry as presented by Clements [1985], although an earlier version can be found in Goldsmith [1981]. Consider again the place assimilation rule (2). This rule can be formalized roughly as in (6a); it changes the representations in (6b) to those in (6c). (In rules, insertion is notated by a broken association line.)

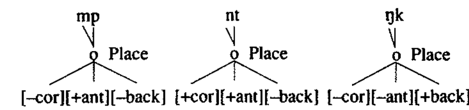
(6)
a. Place Assimilation Rule



b. Input Representations



c. Output Representations



The naturalness of place assimilation, then, follows from the hypothesis that it is a single operation – insertion of an association line – on a single element of the representation – the Place node.

Since the hierarchical representation of the distinctive features is fixed and universal, the only simple rules will be operations either on individual features or the class nodes like Place that dominate them. Arbitrary subsets of the features will require far more complex rules, and so they should be observed much less frequently. We are in a position, then, to establish empirical prerequisites for arguing for the nature of feature geometry: any subset of the features that appears frequently in phonological rules should be dominated by a single class node of the geometry. We will soon explore these questions, but first we must establish what criteria besides assimilation are available to us.

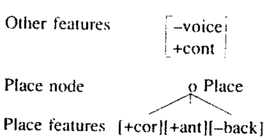
2.2 Nonlinear Operations and Well-Formedness Conditions

We have seen that spreading – that is, insertion of an association line – is the mechanism by which assimilation processes are expressed. Not surprisingly, nonlinear phonology recognizes another basic operation on association lines, deletion of the line itself, known as delinking. This corresponds to the traditional process of reduction.

Consider, for example, the very common phnonological process (and historical sound change) by which *s* becomes *h*. This reduction is essentially the loss of the supraglottal articulation with retention only of the open glottis gesture. Similarly, in English dialects and in some Ethiopian Semitic languages glottalized consonants *p*', *t*', *k*' become glottal stops. This particular type of reduction is known traditionally as debuccalization, and the basic conception of it in feature-geometric terms is due to Goldsmith [1981] and Clements [1985].

With the ideas we have already developed, we can analyze debuccalization as delinking of the Place node. The now placeless consonant lacks supraglottal articulation, so it is the purely glottal *h* or *ʔ*. For example, the rule changing *s* to *h* might be written as in (7). (We notate delinking with a crossed-out association line.)

(7)
Formalisation of $s \longrightarrow h$



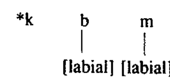
Spreading and delinking, then, are the two basic operations on nonlinear phonological representations, and they correspond respectively to the traditional notions of assimilation and reduction. There are also two basic constraints on the well-formedness of representations that have important effects in phonology. We have already seen the first of these, the Line-Crossing Prohibition. The second constraint, imperspicuously known as the Obligatory Contour Principle (OCP), corresponds in a loose way to the traditional notion of dissimilation. The OCP is stated by Goldsmith [1976] as in (8) [see also Leben, 1973; McCarthy, 1979, 1981, 1986]:

(8)
Obligatory Contour Principle (OCP)
Adjacent identical elements are prohibited.

The 'elements' referred to in the OCP are, of course, the elements of our theory of representation, the features or the featural groupings. For example, the OCP ensures that a geminate consonant like *pp* is represented as a single segment from a featural standpoint that branches to two syllabic positions, occupying the space of a cluster. The universality of the OCP is a matter of controversy [see McCarthy, 1986, Yip, 1988, and Odden, 1988]; it is also possible that languages differ in the domain of the OCP (syllable, word, etc.) or its persistence through the derivation (whether it holds of simple morphemes, word phonology, or phrase phonology).

The role of the OCP in accounting for dissimilatory phenomena can be illustrated by an example like the following, which will be elaborated on later. In Arabic, root morphemes are normally composed of a sequence of three consonants, like *ktb* 'write'. With rare exceptions, Arabic root morphemes cannot contain more than one of the labial consonants *f*, *b*, or *m*. Therefore, root morphemes like **fbm*, **bfk*, **kbm*, and so on are ill-formed. This limitation of a root morpheme to at most one labial consonant is clearly dissimilatory, and it is expressed by the OCP. A hypothetical root morpheme that contained two labial consonants would necessarily contain two specifications for labiality (adjacent to one another, as we shall see later):

(9)



But this contravenes the OCP; adjacent identical specifications for [labial] are ill-formed. Dissimilation in general can be related to this constraint.

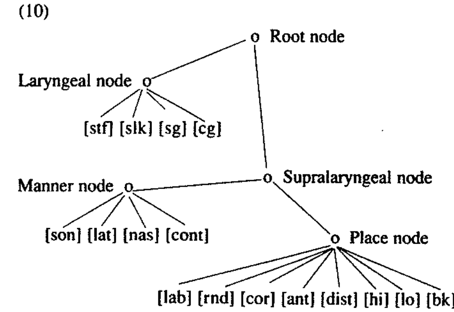
Yet another effect of the OCP involves the Place node directly, although it does not correspond in an obvious way to dissimilation. In many languages, the only permissible consonant clusters are those whose members agree in place of articulation. So, for example, in Ponapean, the only permissible consonant clusters are geminates (*urenna* 'lobster') or homorganic ones (*nampar* 'trade-wind season'). By virtue of the OCP, the geminates must be represented by a single segment branching to two syllabic positions. The OCP also demands that homorganic clusters be represented with a single Place node branching to two segments. This equivalence between geminates and homorganic clusters, with branching at two different structural levels, occurs in many languages. It is accounted for only in a theory that incorporates both the OCP and the Place node [Itô, 1986].

2.3 The Gross Geometry

We begin by examining a particularly interesting and complete characterization of feature geometry, due to Clements [1985].

The phonological features are the terminal nodes of the hierarchical structure. The features in general correspond to those in Chomsky and Halle [1968], but with the addition of a set of articulatory features for laryngeal state ([stiff vocal cords], [slack vocal cords], [spread glottis], and constricted glottis]) [Halle and Stevens, 1971] and the feature [labial] [Anderson, 1971].

(10)



The empirical content of the theory of feature geometry lies in its characterization of the class nodes, the abstract preterminals of this tree that express claims about featural subgrouping. In this particular model, there is a major bifurcation of features into one set – the Laryngeal node – that characterizes states of the glottis and another set – the Supralaryngeal node – that characterizes states of the supraglottal articulators. The Supralaryngeal node separates along familiar lines into manner features and place features. The entire structure is dominated by a single node, the Root, that corresponds to the unity of a single segment.

But the close match between the theory of featural subgrouping expressed by the class nodes in (10) and familiar articulatory and functional classifications is no reason to embrace it. Rather, we must establish its adequacy by testing it against phonological rules. We have established two operations and two constraints on well-formedness that are basic to nonlinear phonology. The character of our theory is such that each operation and constraint is predicted to operate on each class node of the feature geometry in some reasonably well-attested linguistic phenomenon. In other words, we should be able to freely combine the predicates of our theory of representations and our theory of operations and constraints and, in each case, come up with some real rule that languages have. As it happens, the locality requirements expressed by the Line-Crossing Prohibition are presupposed by the other cases, so in what follows we limit our attention to spreading, delinking, and the OCP.

We begin with the Root node, the structural instantiation of a single segment. Spreading of the Root node implies spreading of all the features dominated by the Root node, which is of course the entire set of features. Spreading of the Root node, then, is total assimilation, an impeccably justified process cross-linguistically. Delinking of the Root node, on the other hand, is reduction of a segment to Ø – that is, deletion of the segment. In particular, for reasons that space limitations do not permit us to explore here, delinking of the Root node corresponds to the well-attested process of deletion with compensatory lengthening [Prince, 1975; Ingria, 1980; Hayes, 1987]. And evidence that the OCP holds of Root nodes comes from the behavior of tautomorphemic geminates and elsewhere [McCarthy, 1979, 1981, 1986; Hayes, 1986a, b; Schein and Steriade, 1986].

We also find a complete paradigm of observed phonological processes corresponding to the different manipulations of the Laryngeal node. Although simple assimilation of voicing might be regarded as spreading of the Laryngeal node, such evidence is not probative; we could as well regard it as spreading of the single feature [voice] rather than the class node dominating it. Instead, we must look to a language like Classical Greek, with three stop series: voiceless unaspirated *p*, *t*, and *k*; voiceless aspirated p^h, t^h and k^h, and voiced *b*, *d*, and *g*. In Greek, stop clusters regressively assimilate in both voicing and aspiration. In other words, the Laryngeal node spreads, since the laryngeal features assimilate as a group.

Delinking of the Laryngeal node corresponds to a particular kind of reduction: the neutralization of the various series of stops in favor of the unmarked category voiceless unaspirated. For example, Thai has a three-way distinction between voiced, voiceless aspirated, and voiceless unaspirated stops. Delinking of the Laryngeal node in syllable-final position reduces all three categories to just the unmarked one [Clements, 1985].

OCP effects on the Laryngeal node occur as well. In Seri [Marlett and Stemberger, 1983], the only laryngeally distinctive consonant is glottal stop. Glottal stops in Seri are subject to a dissimilatory process: syllables of the form *ʔVʔ* lose the second *ʔ*. Since *ʔ* is otherwise permitted syllable-initially and finally, this rule is evidently responding to the OCP violation of having adjacent identical specifications of the Laryngeal node [Yip, 1988]. Similarly, in Japanese, the constraint known as Lyman's Law prohibits the occurrence of more than one voiced obstruent within a word of the native vocabulary [Itô and Mester, 1986]. And in Harauti [Allen, 1957] only one aspirated consonant (voiced or voiceless) is permitted in each word.

Of course, these processes could be regarded as OCP effects on individual features, rather than on the Laryngeal node itself. A more persuasive case is presented by the co-occurrence restrictions on consonants in root morphemes of Proto Indo-European. Proto Indo-European root morphemes are usually of the form CVC, and this language is traditionally analyzed (not uncontroversially) as having three series of stops: voiceless *p*, *t*, *k*, and k^w; voiced *b* (rarely), *d*, *g*, and g^w; and murmured *bh*, *dh*, *gh*, and g^wh. Naively, what we expect to find from a dissimilatory OCP effect on the Laryngeal node is a prohibition of root morphemes containing two consonants from the marked categories voiced and murmured; root morphemes like *dVg* and *dhVgh* should be ill-formed.

The facts are somewhat different, although they turn out to be entirely compatible with this view. All possible combinations of the voiceless, voiced, and murmured distinctions are given in (11), with the ill-formed ones designated by *:

(11)

vcls vcls	vcd vcls	*mur vcls
vcls vcd	*vcd vcd	mur vcd
*vcls mur	vcd mur	mur mur

As we expect, root morphemes containing two consonants of the unmarked category voiceless are permitted, and root morphemes containing two consonants of the marked voiced category are prohibited. But, contrary to what the OCP alone tells us, root morphemes containing two murmured consonants are also permitted.

The answer to this puzzle lies in accounting for the other two prohibited root-morpheme types, the combinations of voicelessness and murmur in either order. We can exclude roots of this type while permitting roots with two murmured consonants by positing another rule, which spreads murmur to a consonant not endowed with any Laryngeal node (that is, voiceless). The effect of the OCP on the Laryngeal node is partly masked by this independently motivated assimilation process.

Up to this point, then, we obtain a complete paradigm of spreading, delinking, and OCP effects for each class node we have considered. As we move on, however, we discover that the paradigm is less complete, and this observation leads us to reduce the model in (10) to a somewhat simpler one. The general point to bear in mind is that this model constitutes en empirical hypothesis about how features are grouped, a hypothesis that we can straightforwardly test by combining the theory of class nodes with the theory of phonological operations and constraints.

The Manner node, although it has some attractiveness as a plausible classification of features, turns out not to fulfill any of our criteria. Although some individual manner features do in fact assimilate, we do not ordinarily find phonological rules in languages that assimilate a set of manner features [Clements, 1985]. Similarly, delinking of the Manner node would correspond to a reduction process that, for example, changed all fricatives, nasals, and liquids into the unmarked manner class, oral stops. This sort of phonological rule is also unknown. And finally, dissimilatory OCP effects on the Manner node have not been observed.

We see, then, that the Manner node, unlike the Laryngeal node and Root node, does not interact in the expected way with the theory of phonological operations.

Since the evidence for any class node hinges on this criterion, we must conclude that the Manner node does not exist – there is no place in the feature geometry for a class containing all and only the manner features.

The Supralaryngeal and Place nodes turn out to have apparently complementary functions when we examine how they behave in phonological rules. Spreading of the Place node corresponds to the well-attested phenomenon of place assimilation. But spreading of the Supralaryngeal node, as distinct from spreading of the Place node, is known from only one or two examples that are subject to plausible reanalysis. On the other hand, Clements [1985] identifies the phenomenon of debuccalization with delinking of the Supralaryngeal node, while delinking of the Place node does not have any obvious phonological counterpart. Finally, OCP effects on the Place node are well estabilshed, as in the discussion of Ponapean in section 2.2, but OCP effects on the Supralaryngeal node have not been reported. The remarks here and below about the status of the Supralaryngeal node apply with equal force to the more limited conception of this node urged by Sagey [1986]. In her model, the Supralaryngeal node dominates only the feature [nasal] and the Place node.

What emerges, then, is that the theory in (10) significantly overgenerates: free combination of this theory with the rules and constraints predicts nonexistent phenomena of Supralaryngeal node spreading, Place node delinking, and Supralaryngeal node OCP effects. If we were to eliminate the Supralaryngeal node, however, we would solve this problem.

The crucial factor here is the identification of debuccalization with delinking of the Supralaryngeal node. This initially seems plausible because when, for example, a glottalized stop *t'* becomes *ʔ*, it loses not only its place specification [coronal] but also its manner specification [– continuant]. Delinking of the Supralaryngeal node ensures loss of both manner and place features in debuccalization.

But debuccalization could as well be regarded as delinking of the Place node. To see why this is so, consider the following. The laryngeally articulated consonants *h* and *ʔ* that are derived by debuccalization cannot bear distinctions in the manner features, regardless of the feature geometry we impose on them. For purely articulatory (or definitional) reasons, *h* and *ʔ* cannot carry distinctions for the feature [continuant] (since [continuant] refers only to supraglottal obstructions). An underlying phonological distinction in [nasal] for *h* and *ʔ* is perceptually unlikely or impossible. *ʔ* cannot be perceptually distinctive for [nasal], since glottal closure is obviously incompatible with nasal airflow. With *h*, even when voiced, the lack of resistance in the oral vocal tract would significantly reduce nasal airflow, rendering the nasality essentially inaudible.

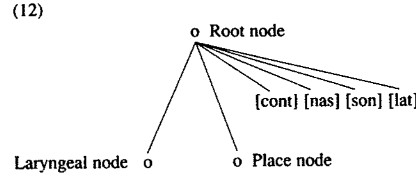
The connection between [nasal] and the Supralaryngeal node has several other problems as well. First, it fails to account for the fact that lack of distinctive nasality in *h* and *ʔ* is one part of a much more pervasive syndrome in which glides, fricatives, and laterals are also never distinctively nasalized [Ladefoged, 1971]. Since all of these other consonants do have Supralaryngeal (and Place) nodes, they are incorrectly predicted to bear nasal distinctions. Whatever the explanation for this phenomenon is, it is

likely to account for *h* and *ʔ* and unlikely to rely on any property of the feature geometry. Second, attachment of [nasal] to the Supralaryngeal node predicts that *h* and ˀ cannot even be nondistinctively nasalized, since they lack Supralaryngeal nodes entirely. Yet in Sundanese, kymographic evidence [Robins, 1957, pp. 98–103] reveals that under some conditions *h* is nasalized by a general process of nasal harmony in that language. Furthermore, Osamu Fujimura points out to me that under some conditions English can have articulatorily nasalized *ʔ*. Third, although the absence of a Supralaryngeal node in *h* and *ʔ* can account for why those segments do not check the propagation of nasality in nasal harmony systems, in all languages the supraglottally articulated vowels and in some languages glides and consonants as well behave in the same way. That is, nasalized vowels in nasal harmony systems show that the presence of a Supralaryngeal node alone cannot determine when nasal harmony is blocked. Finally, Piggott [1987] has amassed a considerable array of evidence from observations about the source of nasal harmony supporting the claim that [nasal] is immediately dominated by the Root node rather than the Supralaryngeal node.

All of these considerations mean that identification of debuccalization with delinking of the Supralaryngeal node serves no useful purpose; delinking of the Place node, which would otherwise not exist, fills the same role. The loss of manner distinctions in debuccalization follows from independently necessary properties of articulation, the definitions of the manner features, and the characterization of distinctively nasalized segments.

We see, then, that we can supply a complete paradigm of phonological processes corresponding to the different operations on the Place node, but we find no good evidence of the same sort for the Supralaryngeal node and the Manner node. The theory of feature geometry, then, should be restructured to assert a simpler view of featural classifications, with a Root node, a Laryngeal node, and a Place node only. We will temporarily dispose of the refugee manner features as daughters of the Root node; later we will settle them permanently. The resulting model appears in (12):

(12)



We predict that each individual feature and each class node in (12) is subject to spreading, delinking, and OCP effects. This is not quite right, as we will see later, but it is very nearly true.

2.4 The Meaning of the Class Nodes

The reduction of the feature geometry to (12) provides us with another way of looking at this theory. In particular, the elimination of the Supralaryngeal node means that the remaining structure of class nodes corresponds rather closely to the traditional notion of a multivalent opposition. Multivalent oppositions, contrasted with binary ones, are simply those with more than two terms.

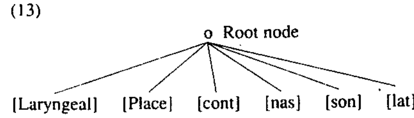
Although laryngeal oppositions are frequently binary, they can be ternary (as in Thai) or quaternary (as in Sanskrit). Place oppositions are rarely binary (as in Kitsai, a language with coronals and velars but no labials), but they are usually at least ternary and may involve higher orders, depending on the analysis. Positing Laryngeal and Place nodes of the feature geometry enables us to decompose these two multivalent oppositions into a set of binary features, while still retaining the underlying phonological unity of the opposition that the facts require. In other words, seen from this light feature geometry is a theory of nonbinary contrasts in binary terms.

At this point it is worth comparing the perspective offered by feature geometry with another view of multivalent oppositions, *n*-ary distinctive features. Although the laryngeal distinctions are analyzed with more than one *n*-ary feature by Ladefoged [1975] and Williamson [1977], the treatment of the place distinctions meshes rather closely with the theory of feature geometry. The places of articulation are specified by an *n*-ary feature [Place], which assumes either integer values related to distance from the glottis (e.g., [6Place] is bilabial and [4Place] is dental) [Williamson, 1977] or substantive values ([[labial]Place] and [[dental]Place]) [Ladefoged, 1975]. The multivalent place opposition, then, is expressed by a multivalent feature.

All of the arguments in favor of the class node Place apply with equal force to the *n*-ary feature [Place]. Place assimilation can be seen as spreading of this feature, debuccalization is delinking of this feature, and a phenomenon like that of Ponapean in section 2.2 can be analyzed as an OCP effect on the [Place] feature. This is the expected outcome: because individual features are subject to all of the operations that class nodes are subject to, reducing a class node to an *n*-ary feature changes nothing at this level of analysis.

We can summarize our observations about the similarity between feature geometry and *n*-ary features with the tree in (13):

(13)



This tree lacks the essential property of feature geometry, the hierarchical structure represented by the class nodes, while still retaining the nonlinear representation.

Are there any differences, then, between these two very different theories of essentially the same problem? Explicit discussion of this question is rare, and the arguments that are raised are unpersuasive, tending to emphasize methodological rather than empirical differences:

(1) The success of the feature-counting evaluation metric rests on binary features [Halle, 1957]. Feature geometry and *n*-ary features respond in the same way to the failure of an evaluation metric that just counts binary features. Place assimilation is a natural rule, so it should be statable with a single feature (or its class node equivalent), rather than a list of binary-valued place features.

(2) *n*-ary feature theory countenances rules of the form [*m*Place] → [*m+1*Place], which do (or do not) occur. In fact, rules of this sort are at best extraordinarily rare (except perhaps for tongue height in vowels). In any case, this argument presupposes that all *n*-ary feature theories have integer values which, as we have seen, is false in fact and in principle. Moreover, it incorrectly assumes that integer values themselves somehow drag along with them the whole apparatus of arithmetic.

(3) The number of possible *n*-ary feature values is infinite. This argument confuses the metatheory with the theory itself.

(4) *n*-ary features are excessively atomistic, distinguishing, say, [[dental]Place] from [[alveolar]Place], when in fact these never contrast directly, both being subsumed under the single place feature [coronal]. This objection stems from a methodological rather than a principled difference between the two types of feature theories – close adherence to phonetic observations might lead to distinguishing dental and alveolar directly, while phonological evidence points toward invoking a secondary property like [distributed]. Clearly, the values of the *n*-ary place feature can be identical to the places characterized by the equivalent binary features.

(5) Multivalent oppositions which require incompatible specifications of binary features are more appropriately analyzed with *n*-ary ones [Williamson, 1977]. This argument is relevant to the characterization of tongue height (with the incompatible [+high, +low]), but not to place distinctions. Combinations of more than one place specification are required to account for complex segments like double stops (e.g., $\widehat{gb}$), and these are actually posited in both theories [Williamson, 1977; Sagey, 1986].

(6) *n*-ary features can account for incomplete assimilations that involve movements along a scale in the direction of the triggering segment [Williamson, 1977]. If, for example, *p* becomes *t* after *i*, the change from labial to dental can be viewed as assimilation toward palatality along the scale defined by the *n*-ary [Place] feature. This is, in a strict sense, incomparable with feature geometry because it assumes some external theory of assimilation, never made explicit, that cannot be reduced to autosegmental spreading. In fact, the case is much overstated; for example, predicted rules like *p* becomes *t* after *k* are never found.

(7) The *n*-ary [Place] feature does not permit negative place specifications like [–coronal] of binary feature theory, and, since these specifications do not have a classificatory function in phonological rules, the *n*-ary feature is to be preferred. As we will see below, the same condition – a prohibition on negative values – is also imposed on feature geometry.

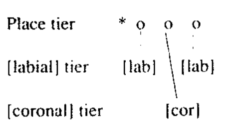
These considerations suggest that empirical differences between the Place node and the [Place] feature will be hard to come by, and in truth they are. Nevertheless, one fairly persuasive argument emerges from considerations of locality in Arabic root-morpheme cooccurrence restrictions, although ultimately this too can be subverted.

Recall that Arabic triconsonantal root morphemes are subject to a constraint prohibiting them from containing more than one labial consonant *f*, *b*, or *m*. The most straightforward account of this constraint on morpheme structure is a restriction on the distribution of the feature [labial] – [labial] can appear at most once in a root morpheme, as a consequence of the OCP. Restricting [labial] in this way appears simple until we consider the problem of locality, embodied in the adjacency requirement of the OCP. The restriction on [labial] is nonlocal in the sense that it applies to possibly nonadjacent segments, the first and third consonants in the root morpheme. Any intervening consonant, regardless of its place of articulation, is transparent to this restriction on the distribution of [labial].

To formalize this cooccurrence restriction in a way consistent with locality requires representing the feature [labial] separately from the features characterizing the other places of articulation. In nonlinear phonological terms, this means that the feature [labial] must occupy its own tier, separate from features like [coronal], and moreover, negative specifications like [–labial] must be excluded. This means that [labial] is a so-called privative feature, one that is either present or absent, rather than a feature that assumes + and – values.

An ill-formed root morpheme like *btf* containing two labial consonants would look like (14), with adjacent identical [labial] features in contravention of the OCP:

(14)



To comply with locality requirements, the middle consonant cannot have any specification on the [labial] tier (else the two instances of the feature [labial] would be nonadjacent). As we have seen, this is accomplished by representing the different features on different tiers and by treating them privatively.

The broader point of this example is that, although the different place features are unified by their subordination to the Place node of the geometry, they also exercise a considerable degree of phonological independence. In particular, the place features are transparent to one another, with the prohibition on cooccurrence of labials seeing right through intervening nonlabial consonants.

A result of this sort is not obviously available to a theory incorporating an *n*-ary [Place] feature. In this approach, the ill-formed root morpheme *btf* would be represented as in (15):

(15)
[Place] tier [[lab]Place] [[cor]Place] [[lab]Place]

Although this contains identical specifications for the feature [Place], they are not adjacent to one another. Unifying the place distinctions into a single *n*-ary feature runs afoul of locality because it fails to account for the mutual intertransparency of the different place specifications. Only binary features in a feature geometry account for both the unity and the separateness of the various place specifications.

Although this argument does provide some means to distinguish between the two theories of multivalent oppositions, it too can be subverted by technical means. We solve the locality problem if we say that different *values* of the *n*-ary [Place] feature define different autosegmental tiers. This has the look of special pleading, since different values of binary features like [continuant] or [nasal] cannot be represented on separate tiers, or else we cannot account for opacity effects like those in the Guaraní example of section 2.1. But there is a compensating advantage to this approach. In the binary feature theory, we needed to stipulate that place features like [labial] are privative, without negative values, this result falls out immediately from the nature of the *n*-ary [Place] feature.

Let us now sum up. Feature geometry is essentially a theory of multivalent oppositions of glottal state and place of articulation. There exists a nearly equivalent theory of the same domain that is non-hierarchical, although it is nonlinear. At the level of the gross architecture of featural structure, the two theories are not distinguishable from one another.

3. Feature Dependency and the Fine Structure of the Geometry

The results up to this point are summarized by figure (12). So far as we know, the characterization of the Laryngeal node and its dependents in this model is satisfactory. But closer scrutiny of the Root node and the Place node turns out to be quite profitable. We consider each of them in turn.

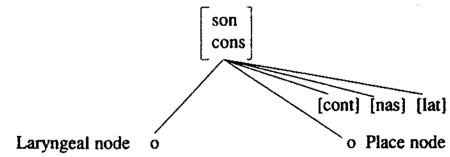
3.1 The Root Node

At the moment, the features immediately dominated by the Root node include the manner features [continuant], [nasal], and [lateral], as well as the major class feature [sonorant]. To the latter we might also add the major class feature [consonantal].

The two major class features [sonorant] and [consonantal] differ from all other features in one important respect: they arguably never spread, delink, or exhibit OCP effects independently of all other features. Expressed somewhat differently, this means that the major class features do not assimilate, reduce, or dissimilate except in conjunction with processes that affect the entire segment.

Therefore the major class features should not be represented on separate tiers as dependents of the Root node – otherwise they would be expected to spread, delink, and so on just as the other features do. Instead, the major class features should literally form the Root node, so that the Root ceases to be a class node and instead becomes a feature bundle itself [Halle, 1988; Sagey, 1986; Schein and Steriade, 1986]:

(16)



All the other features are now said to be in a *dependency* relation [Mester, 1986; Sagey, 1986] with the major class features. This means that any operation on the major class features – spreading, for example – implies an operation on the features subordinate to the root.

The feature [lateral], although it is usually regarded as a manner feature, nevertheless displays a significant association with the coronal place of articulation [Levin, 1987]. We shall therefore give it a preliminary classification with the place features and delay detailed consideration of it until we examine the Place node.

This leaves only the two true manner features [continuant] and [nasal] as immediate dependents of the root. If they are separate from the root, as they are in (16), then we predict that they will display a full paradigm of the effects of the nonlinear operations. In fact, this is very nearly the case:

Spreading

[Continuant]. The postvocalic spirantization rules of Spanish, Tigrinya, and Biblical Hebrew (in which *pbtdkg* → *ϕβθðxɣ*) are possible examples of this process, although they are open to an alternative interpreta-

tion. A better example may be the English dialectal rule changing *z* to noncontinuant *d* before noncontinuant *n*: business → [bɪdnɪs].

[Nasal]. Nasal assimilation (harmony) in Guaraní (section 2.1).

Delinking

[Continuant]. In Yucatec Maya [Straight, 1976; Lombardi, 1987], the first member of a cluster of homorganic stops or affricates separated by a word boundary is subject to a process of deocclusivization. If the first consonant is a stop, it becomes *h* (*k*# *k* → *h*# *k*); if it is an affricate, it becomes a fricative (*c*# *t* → *s*# *t*). We can unify these two phenomena as delinking of [–continuant]: a stop becomes a segment with no value for [continuant], which is incompatible with supraglottal articulation, while an affricate loses its stop portion (see below).

[Nasal]. The early Scandinavian sound change where homorganic nasal-stop clusters became geminates (*mp* → *pp*) is a possible example of this process. A more complex example from Kaingang [Henry, 1948] changes the nasals *m, n,* and *ŋ* and the prenasalized stops *mb, nd,* and *ŋg* to the homorganic voiceless stops *p, t,* and *k* before voiceless consonants, in each case delinking [nasal] and then regressively spreading [–voice].

Obligatory Contour Principle

[Continuant]. In Piro [Matteson, 1965], clusters of two fricatives *s, š,* and *x* cannot occur – that is, there is a dissimilatory OCP effect on [+continuant]. A possible dissimilatory OCP effect on [–continuant] can be seen in the treatment of stop clusters in Sierra Popoluca [Clements, 1985, p. 239]. In Yucatec Maya [Straight, 1976; Lombardi, 1987], CVC root morphemes are subject to the following cooccurrence restriction: if both consonants in the root morpheme are [+continuant] (fricatives or affricates) and neither is glottalized (therefore *s, š, c,* and *č*), then they must be identical. In other words, by the OCP the two root-morpheme consonants must share a single specification [+continuant], from which it follows that they share a single root node, from which it further follows that they are identical in all other feature specifications.

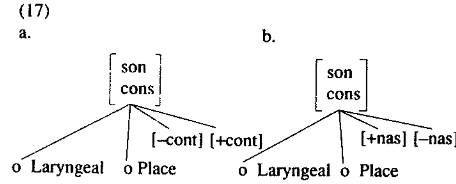
[Nasal]. No cases known. [See Hayes, 1986b, for related discussion.]

The distinction we make between the major class features [sonorant] and [consonantal] as actually forming the root node and the manner features [continuant] and [nasal] as dependents of the root node makes two additional predictions:

First, by the logic of the dependency relation, the presence of a subordinate or dependent feature entails the presence of the superordinate or dominating feature. In the case at hand, because all other features are dependents of the major class features, we could make no featural distinctions at all if the major class features were not specified. From this it follows that all languages must distinguish sonorants from nonsonorants and consonants from nonconsonants. In fact, this is the case: all languages have both sonorants and obstruents, and all languages have both consonants and vowels. No such prediction is made in the case of the manner features, which have no dependents. This too is the case: there exist languages with only oral consonants (Puget Sound Salish and other languages of the Pacific Northwest), and there exist languages with only stop consonants (a common situation in Australian languages)..

Second, because [continuant] and [nasal] are dependents of the root node rather than part of it, their values can change within the span of a single phonological segment [Campbell, 1974; Anderson, 1976; Leben, 1980; Clements and Keyser, 1983; Sagey, 1986]. That is, we can have representations like those in (17):

(17)



(17a) represents an affricate, a single segment with an internal sequence of closure and release; (17b) represents a prenasalized consonant, a single segment with an internal sequence of nasal and oral gestures. Although important questions about these so-called contour segments remain to be worked out, particularly in light of the observations about Yucatec Maya affricates and Kaingang prenasalized stops in the examples above, this hypothesis provides a starting point for the study of this problem.

We have seen, then, that the root node and its immediate dependents provide a fairly natural classification of the features for which considerable phonological support is forthcoming. The root node itself is composed of the major class features; the immediate dependents of the root node are the two most important manner features.

3.2 *The Place Node*

At the outset, we can distinguish two distinct hypotheses about the internal organization of the Place node. (18) presents them in a nonrigorous, incomplete way:

(18)

a. Place of Articulation (POA) Theory

b. Articulator Theory

The POA theory [Chomsky and Halle, 1968; Clements, 1985; Archangeli and Pulleyblank, 1986] expresses places of articulation primarily in terms of values of the features [coronal] and [anterior]. Segments that are coronal are produced with the blade or tip of the tongue; segments that are anterior are produced with any (physically possible) articulator with a primary constriction inclusively forward of the palato-alveolar region. Thus, [–cor, +ant] characterizes labials, [+cor, +ant] characterizes dentals and alveolars, [+cor, –ant] characterizes palato-alveolars, and [–ant, –cor] characterizes palatals, velars, and so on.

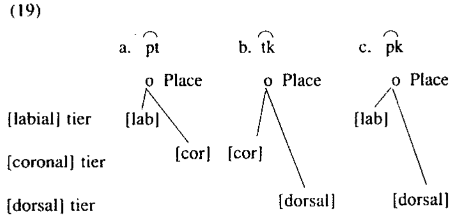
Articulator theory [Halle, 1988; McCarthy, 1985; Sagey, 1986; Mester, 1986] distinguishes segments by the active articulator making the constricting gesture rather than by place of articulation. Gestures by the lips, both upper and lower, are characterized by [labial]; as in POA theory, [coronal] refers to the blade or tip of the tongue, and gestures by the tongue body are characterized by the feature [dorsal].

There are quite a few arguments that support Articulator theory over POA theory. POA theory places crucial reliance on the feature [anterior]. This feature is problematic in any case: it cannot be defined in either articulatory or acoustic terms (it refers neither to a distinct articulatory gesture nor to a distinct acoustic outcome). Furthermore, [anterior] appears to function only in its definitional role of characterizing place distinctions; it does not, by itself, characterize a class of segments referred to consistently by phonological processes, as Kenstowicz and Kisseberth [1979] have noted. POA theory predicts that there should be spreading, delinking, and OCP effects on the feature [anterior] alone; these are not found.

Articulator theory, unlike POA theory, provides a coherent account of the class of consonants known as complex segments [Sagey, 1986], including among others labiovelars, double stops, and perhaps clicks. Complex segments are characterized by constrictions at two separate points in the vocal tract, both of which are primary in the sense that both function phonologically like the single constriction of a simplex segment. There are two crucial (and related) observations about complex segments that any theory must account for: (i) the two constrictions are formed by distinct articulators, and (ii) the two constrictions are phonologically unordered, even though they may be sequenced in speech production.

Articulator theory accounts for these observations by representing complex segments with two different articulators linked to a single Place node (and therefore expressed within the span of a single segment) [Sagey, 1986]:

(19)

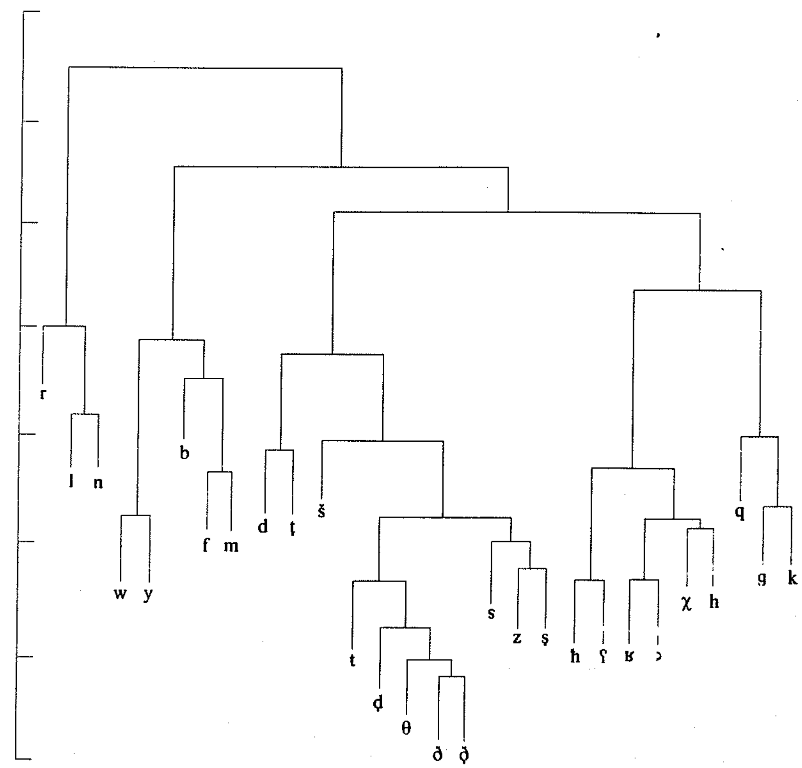


The first observation is accounted for trivially – the two constrictions of a complex segment involve gestures by distinct articulators because Articulator theory has no other way to represent two constrictions within the span of a single segment. The second observation – the lack of phonological linear ordering of the two gestures – follows from the segregation of the different features onto different tiers (see section 2.4). Elements on different tiers linked to the same node can have no linear ordering relations.

Evidence from phonological processes also supports Articulator theory. Consider, for example, the Yucatec Maya rule cited earlier. In this language, stops become *h* and affricates become fricatives before homorganic obstruents. To be precise it is sufficient that the two consonants share one articulator rather than be produced at exactly the same place of articulation. For example, *tč*, although not homorganic in the strict sense, nevertheless undergoes this rule to become *hč*. In POA theory, the cluster *tč* is no more homorganic than, say, the cluster *pt*, which does not undergo the rule (both differ in exactly one place feature). But in Articulator theory, both consonants of *tč* are specified for the [coronal] articulator feature, while the two consonants of *pt* have entirely different specifications.

Finally, evidence from OCP effects like the root-morpheme cooccurrence restrictions of Semitic (see section 2.4) also provides a compelling argument for Articulator theory. The dendrogram in (20) presents the results of cluster analysis on consonant cooccurrence restrictions in Arabic. (Cluster analysis was by the compact – complete linkage – method on the euclidean distances of the consonant phonemes based on the measure of similarity described in the text.) The frequency of pairs of cooccurring consonants was obtained for all of the 3,330 verbal roots in a dictionary of Modern Standard Arabic. For the purpose of an analysis, a measure of similarity was obtained by computing the difference between the observed frequency (scaled to eliminate effects of the intrinsic frequency of different consonants) and the scaled frequency expected if consonant cooccurrence were random. (Subscript dots on *ṭ, ḍ, ṣ*, and *ð̣* indicate so-called emphasis, constriction in the mid pharynx concomitant with the coronal constriction. *θ* and *ð* are the voiceless and voiced dental fricatives, respectively. *ħ* and *ʕ* are the voiceless and voiced glides or fricatives articulated in the lower pharynx. *q* is a voiceless uvular stop, and *χ* and *ʁ* are the voiceless and voiced uvular fricatives, respectively.)

(20)



Examination of (20) reveals that the major classification of consonants into groups that tend not to cooccur is primarily based on the articulator and major class feature [sonorant], rather than the place of articulation. The most important classifications are the following:

(21)

Labials	fbm
Coronal sonorants	lrn
Coronal obstruents	θðtdszðṭḍṣš
Dorsal sonorants	wy
Dorsal obstruents	kgq
Pharyngeals and laryngeals	χʁħʕhʔ

Within each of these classes, consonants tend not to cooccur. There are some complications, however. First, the failure of the so-called dorsal sonorants (or high glides *w* and *y*) to cooccur may have another explanation, since these consonants exhibit conspicuous phonological peculiarities elsewhere in the language. Second, the uvular stop q and the uvular fricatives χ and ʁ are assigned to different classes. In fact, separate analysis reveals that these three consonants only rarely cooccur. Third, we have no particular articulatory motivation for lumping together pharyngeals and laryngeals. Nevertheless, exactly this set, traditionally known as the gutturals, functions as a class phonologically in a wide variety of phonological processes in Semitic languages.

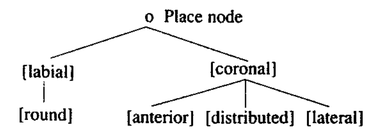
We have already seen how such cooccurrence restrictions are analyzed formally: the dissimilating feature is represented on its own autosegmental tier and is subject to the OCP. Consideration of the full Arabic system reveals that the dissimilating feature is in each case an articulator feature: [labial], [coronal], [dorsal], and [pharyngeal]. Moreover, the sonorant/obstruent distinction shows that the cooccurrence relation is observed relative to the major class feature [sonorant], which dominates the Place node (and therefore the articulator features) in our feature geometry. (18b) contains exactly the articulator features we require except for [pharyngeal], which should properly be added to (18b) to account for languages like Arabic where the pharynx is a major articulator. (18a) or any finer characterization of places of articulation is inconsistent with these observations.

Very similar results hold for Javanese [Mester, 1986; Yip, 1987b]. Yip [1987a] develops this evidence into a powerful argument in support of Articulator Theory: her survey of consonant cooccurrence restrictions in a variety of languages reveals that such constraints are always prohibitions on the repetition of an articulator within some domain. This is exactly what we expect from the influence of the OCP in a model like Articulator Theory.

The demonstration that the primary division of the Place node is into articulators naturally leads to questions about finer distinctions of the individual articulator features. The feature [dorsal] alone is obviously inadequate to characterize the degrees of freedom of the tongue body, and in particular it is an entirely unsatisfactory account of the interactions and lack of them between vowels and consonants. But the complications are so great that space limitations make it impossible for us to explore this question here. The following references provide varied perspectives on the problems and possible solutions: Sagey [1986], Prince [1987], McCarthy [1987], Steriade [1986a, 1987], Mester [1986], Archangeli and Pulleyblank [1986], Clements [1985].

The finer distinctions of the labial and coronal articulators are considerably clearer, however. A view for which considerable independent evidence can be adduced is embodied by the model in (22):

(22)

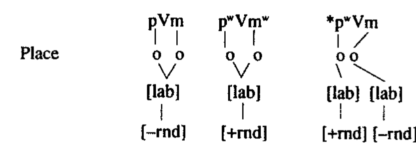


In this approach, [round] is a dependent of [labial] [Sagey, 1986], while [anterior], [distributed], and [lateral] are dependents of [coronal] [Steriade, 1986b; Sagey, 1986; Levin, 1987; Mester, 1986]. Because the articulator features [labial] and [coronal] are privative – that is, they are present (on) or absent (off) – the dependency of [round] on [labial] entails that distinctively rounded segments are also specified as [labial]. This connection makes quite a few testable predictions, as we shall now see.

We might suppose that an association between [round] and [labial] is motivated on purely articulatory grounds. Rather, there is an array of purely phonological arguments for a connection between these two features. A large number of cases from historical and synchronic processes are cited by Campbell [1974, p. 53]; they typically involve languages where k^w becomes p. This process has a natural interpretation if [round] depends on [labial], as Sagey [1986] points out; k^w necessarily involves both the [labial] and [dorsal] articulators, the former entailed by the fact that the segment is [round]. Simplification of this complex segment by loss of the [dorsal] articulator, then, is the fundamental process in the change.

Other evidence for the same conclusion comes from very different domains. In Ponapean, as Mester [1986] observes, a phenomenon of rounding harmony in labial consonants can be straightforwardly explained by the dependency of [round] on [labial]. Ponapean distinguishes four labial consonants, *m*, m^w, *p*, and p^w. Within a root morpheme, the labial consonants must agree in rounding. With [round] as a dependent of [labial], the effect of the OCP on the feature [labial] entails agreement of labial consonants in rounding:

(23)



Because of the dependency relation between [round] and [labial], disagreement in rounding is possible only if the consonants have separate specifications for [labial] – exactly the situation that the OCP prohibits.

Another sort of constraint on the structure of morphemes is presented by Yip's [1988] account of consonant-vowel cooccurrence in Cantonese. In that language (nonround) labial consonants and round vowels may not appear in the same syllable – again an OCP prohibiting the cooccurrence of two [labial] specifications in the span of a single syllable. The particular interest of this case lies in the fact that the distinctively rounded vowels must have a specification for the articulator feature [labial] because of its dependency relation with [round]. A similar account can be given to the prohibition in English of syllable-initial clusters composed of a labial or labiodental consonant followed by *w*.

Finally, we can point to cases like Warlpiri [Nash, 1979b], Igbo [Hyman, 1975], and Tulu [Campbell, 1974; Sagey, 1986], in which processes of rounding harmony or assimilation are blocked by labial consonants. This, then, is spreading of the [labial] feature; it is blocked, as in Guaraní [nasal] spreading (section 2.1), when it encounters another instance of [labial].

The point of this examination of [labial] and [round] is made most forcefully by Campbell [1974]: there is a recurrent association of the labial place of articulation with lip rounding. The dependency of [round] on [labial] expresses this association, and moreover it ties the effects of the dependency to phenomena observed in other areas of feature geometry.

We will not dwell at such great length on the dependents of [coronal]. The first feature we will consider is [distributed], which separates the coronal articulator into two parts, distinguishing the tongue tip ([−dist]) from the tongue blade ([+dist]). The dependency relation, then, is essentially definitional; [distributed] indicates a finer distinction of [coronal]. A result of this essentially identical, mutatis mutandis, to Ponapean comes from Alur, a Nilotic language. Alur distinguishes [−distributed] coronals *t* and *d* from [+dist] coronals *th* and *dh*. Within a root morpheme of Alur, the coronals must agree in their value for [distributed] [Mester, 1986]. A similar constraint is met with in Apache, and other evidence for this dependency relation can be found in the phonology of retroflexion in Sanskrit [Steriade, 1986b].

The next dependent of [coronal] is [anterior]. This is not the same feature that appears in POA theory, however, but rather another finer distinction in [coronal] according to location of the constriction on the passive articulator. Palato-alveolars are [−ant]; alveolars and dentals are [+ant]. Thus, as with [distributed], the dependency relation is essentially a definitional one. Parallel to the cases of Ponapean and Alur, in Ngiyambaa (Australia) we find the following phenomenon [Donaldson, 1980]: Ngiyambaa distinguishes [+ant] distributed coronals (that is, lamino-dentals) *dh* and *nh* from [−ant] distributed coronals (that is, lamino-alveopalatals) *di* and *ni*. The distributed coronals within a root morpheme of Ngiyambaa must agree in their value for [anterior]. Other evidence for this dependency relation comes from assimilatory processes in Chumash [Steriade, 1987], Navajo, and Moroccan Arabic.

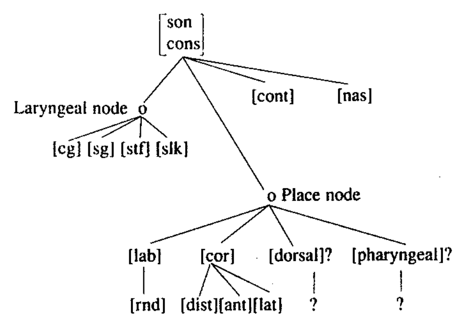
The last dependent of [coronal] to consider is the feature [lateral]. This dependency is somewhat problematic, though, since there exist velar as well as coronal laterals [Ladefoged, 1980]. For example, in Kuman (Papua New Guinea), the velar lateral (conventionally transcribed as *gl*) contrasts with an alveolar lateral *l*. Nevertheless, there is phonological evidence of a significant association between lateral and coronal even in the case of velar laterals [Levin, 1987]. In two different rules of Kuman, the velar lateral alternates with a coronal consonant [Lynch, 1983]. Before *n*, the velar lateral (and *r*) becomes *t*: *yobugl-o* 'his

bone', *yobut-na* 'my bone'. And when preceding another *gl* across a vowel, the velar lateral dissimilates to *r*: /yagl-agl-ka/ → *yar-agl-ka* 'I will plant'. From a phonological standpoint, then, these velar laterals have at least a latent coronal component, consistent with the claim that the feature [lateral] is a dependent of [coronal].

4. Conclusion

Beginning from the initial conception by Clements [1985] in (10), the picture of feature geometry that ultimately emerges is an incomplete one, but well supported in most respects:

(24)



In examining this model, we have emphasized the conception of the theory as two interacting modules, representations and operations.

Clearly, this entire discussion is more in the nature of a research program than an established set of results. Although there are some areas of firm ground, many questions remain. Perhaps the most relevant one at this juncture is the proper relation between a formal phonological model like (24) and the theory of phonetics.

Let us begin by embedding this issue in its historical context. American structuralist phonology during the 1940s and 1950s took a rather dim view of the relation between phonological and phonetic phenomena. One reason for this is that most of what passes today for phonology was then regarded as morphophonemics, an enterprise involving the manipulation of symbols with no phonetic content. In structuralist terms, no principled distinction was made between a process like German final devoicing, the phonetic basis of which is evident, and the formation of the exceptional plural *oxen* in English. Even in structuralist phonemics, the relation between phonology and even elementary phonetics was often a matter of dispute. For example, the debate over whether *h* and *ŋ* should be assigned to the same phoneme in English (because they are in complementary distribution) hinged on whether even minimal criteria of phonetic similarity could be applied.

This situation stands in contradistinction to Jakobson's fundamental insight in the late 1930s that the classification of speech sounds exploited in phonology has a universal phonetic basis. From this idea, which now seems so obvious but which was in fact so difficult to achieve, the subsequent development of the theory of distinctive features and in fact of feature geometry itself constitute a very natural progression.

Nevertheless, the proper role of phonology vis-à-vis phonetics is far from obvious. Chomsky and Halle [1986] limited the projection of phonetics into the phonological theory to a purely classificatory role: the distinctive features are defined in phonetic terms. Moreover, evidence for or against a particular featural distinction was always to be sought in the phonological domain. The theory of feature geometry of Clements [1985] and others, although it enhances the classificatory role of articulatory phonetics in its characterization of the class nodes, adheres to the same methodological premise.

Is the interplay between phonology and phonetics limited to this classificatory function of the distinctive features and their geometry? Or more broadly, what is the proper division of labor between phonology and phonetics? In a sense, this question is unanswerable, since the proper empirical domain of any theory is determined by that theory rather than by external considerations.

At this stage in the development of the two theories, it is neither possible nor especially useful to ask whether some particular phenomenon is within the purview of either one. At best we can apply some rough-and-ready criteria to make the judgement. For example, morphological or grammatical sensitivity, tolerance of lexical exceptions, long-distance effects, recognition of abstract distinctions, control of possible underlying contrasts, and ordered rule interaction are all taken to be criterial for phonological as opposed to phonetic processes. By these standards, most of the phenomena I have discussed are certainly phonological. If we add another standard that is not universally accepted, language particularity, then all of the phenomena are phonological. But I think this misses the point. Rigid discrimination between phonological and phonetic phenomena could only stunt the development of two theories that are still imperfectly understood. The empirical overlap between the two domains presents an opportunity for exploring their interaction rather than an impediment to research.

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