Segmental Hierarchitecture

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0. INTRODUCTION*

In this article we offer a critical overview of some current ideas on the internal structure of segments. Following the prevailing view, we will assume that, firstly, phonological segments are composed of distinctive features and, secondly, that there is a fixed universal set of features from which particular languages make a selection. A prime task of phonological theory, then, is spelling out this universal set of features. In this article, we will not address this issue directly, as such an enterprise would be well beyond the scope of what we aim at here. Rather, our intention is to concentrate on three central areas which, directly or indirectly, form the topic of the other papers in this volume, for which this article will hence provide a background. The first area, which is the topic of section 1, involves the claim that the features characterising phonological segments are organised in a hierarchical structure, involving relations of dependency and/or dominance. In section 2, we discuss the claim that features are essentially unary, either expressed in a theory of underspecification or in a theory of single-valued features. Finally, in section 3 we investigate the major class or categorial features and their relation to the sonority hierarchy.

1. DOMINANCE AND DEPENDENCY

1.1. Background

The motivation for changing the conception of phonological structure propounded in Chomsky & Halle (1968) (henceforth, SPE) to a multi-linear conception (not including the more recent "hierarchical phase") has been outlined elsewhere in some detail (cf. Van der Hulst & Smith 1982; 1985). In this subsection we confine ourselves to discussing the nature of the changes, thus setting the stage for the discussion in the subsequent sections. It will be shown that the difference between the SPE conception of phonological representations and more current conceptions involves the abandonment of three hypotheses, which form the foundation of the SPE approach.

In SPE, phonological representations are conceived of as unilinear strings of segments, where segments are unordered, non-overlapping and unstructured sets of essentially binary features.

(1)
$$\ldots \begin{bmatrix} +F \\ -G \\ -H \end{bmatrix} \begin{bmatrix} -F \\ -G \\ +H \end{bmatrix} \begin{bmatrix} -F \\ +G \\ +H \end{bmatrix} \begin{bmatrix} +F \\ +G \\ +H \end{bmatrix} \ldots$$

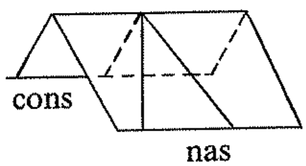
The fact that the features are sequentially unordered entails that a single segment cannot have both values of a particular feature, as this would lead to a contradiction. Let us refer to this as the NO-ORDER HYPOTHESIS. On this point AUTOSEGMENTAL PHONOLOGY differs from the SPE-theory, the crucial idea being that a single "segment" can have two sequentially ordered specifications for a single feature. The prime motivation for this move comes from COMPLEX SEGMENTS, like prenasal consonants, affricates or contour-toned vowels. SPE would permit, at best, the representation in (2a) for a prenasal consonant, whereas phonological considerations point to something like (2b):

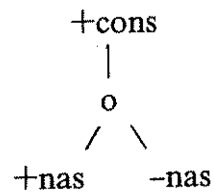
(2) a.
$$\begin{bmatrix} +\text{ cons} \\ \cdot \\ \cdot \\ +\text{ prenasal} \end{bmatrix}$$
b.
$$\begin{bmatrix} +\text{ cons} \\ \cdot \\ \cdot \\ +\text{ nas}, -\text{ nas} \end{bmatrix}$$

The phonological argument is, quite simply, that from the left prenasals show the same behaviour as nasals do, whereas from the right they pattern with nonnasals (cf. Anderson 1976). The same applies to virtually all cases where we deal with complex segments, and a particularly strong case was made with reference to contour-toned vowels. Interestingly, Woo (1969), who argued that contour tones ought to be presented as sequences of two level tones, was forced to claim that such tones cannot occur on short vowels, because she followed SPE in disallowing such sequences "within a single segmental matrix". This claim proved untenable, however, and this had to have the consequence of abandoning the NO-ORDER HYPOTHESIS. This, then, led to the birth of autosegmental phonology.

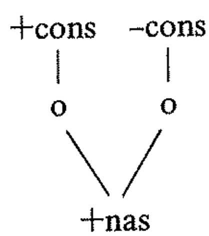
A representation such as that in (2b) (which is not that of autosegmental phonology yet) preserves another constraint on segmental representation inherent to the SPE theory, which is that representations of segments are non-overlapping: the NO-OVERLAP HYPOTHESIS. Phonological argumentation, characteristically involving assimilation processes, was subsequently adduced to abandon this restriction as well in order to allow the expression of the idea that adjacent segments having a property in common literally share a single specified feature.

Clearly, at this point a bracketing notation as in (2b) can no longer be maintained because it does not allow one to represent overlap. To be able to express that every feature can belong to more than one segment, we have to drastically alter our understanding of phonological segments. We have to look upon segments as abstract points to which features, represented on autonomous planes, are associated:

(3) a. 

b. 

Every feature defines a dimension, as the equivalent representations in (3a) and (3b) indicate. Every dimension must be graphically represented on a different line. Now, there no longer is a problem in representing overlapping representations:

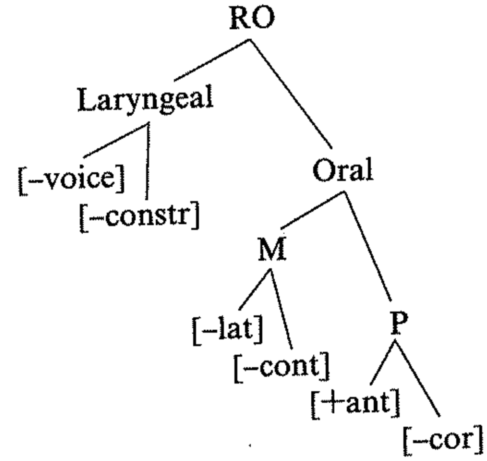
(4) 

In (4) we represent a case where a consonant and a following vowel share the same specification for the feature nasal.

Representations as in (3) and (4) are those of autosegmental phonology. The lines are referred to as ASSOCIATION LINES, linking the features, each occupying a separate TIER, to the node "o" the status of which will be discussed below. In early versions of autosegmental phonology (e.g. Goldsmith 1976), tiers were associated to tiers, the tacit assumption being that the units on the tiers containing the major class features define the number of segments. In practice all features not showing spreading behaviour were grouped into one tier, often called the *segmental tier* (cf. Goldsmith 1976).

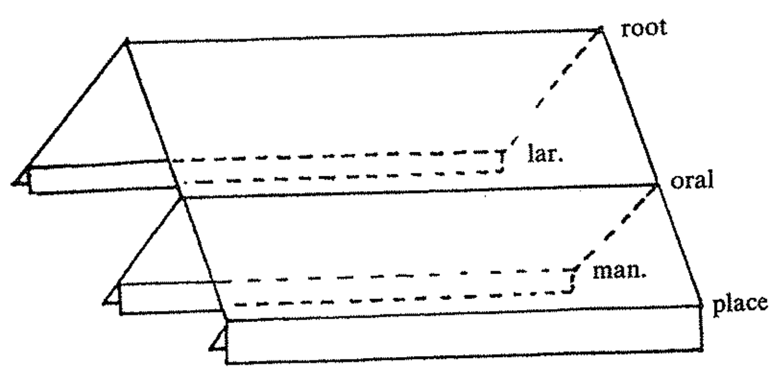
Although different from SPE in having abandoned two restrictions on featural structures, early autosegmental phonology maintains a third important restriction in that the feature set is unstructured, i.e. all features are totally independent with respect to each other: the NO-STRUCTURE HYPOTHESIS. It has long been recognised, however, that features can be grouped together into, for instance, manner features, laryngeal features, place features etc.; standard autosegmental phonology, like SPE, does not reflect this grouping in the actual feature structures. Again, phonological argumentation (which, unlike in the former two cases, will be discussed at length in this article, in section 1.2) has provided reasons for incorporating feature grouping in the formal representations of phonological structure. To simplify the issue for the time being, assume that the feature classes referred to above are those that we want to incorporate. We arrive at the structure in (5):

(5)



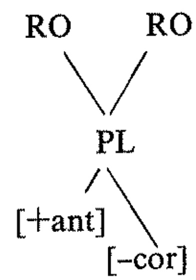
We have given the intermediate nodes, which are called GESTURES by some (in particular, proponents of Dependency Phonology) and CLASS NODES by others, names like P(lace), M(anner) etc. Following current work the top node is labelled RO(ot). In (5) we have not only incorporated the classes mentioned earlier, but we have also grouped the manner and place features together as the oral features. The particular classification here merely serves illustrative purposes. Specific proposals will be discussed in the next section. (5) represents a fragment, showing one segment. A full planar representation is somewhat complicated to represent:

(6)



An immediate advantage of grouping features under labelled nodes is the possibility of representing the frequent occurrence of segmental overlap involving not a single feature, but feature groups. This can now be represented straightforwardly in terms of shared non-terminal nodes:

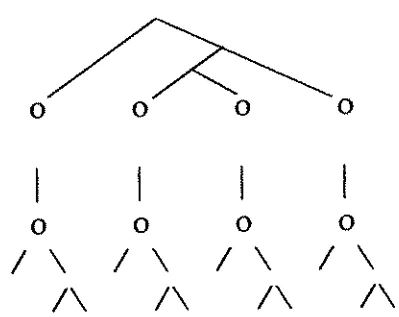
(7)



(7) represents a sequence of two consonants having the same place of articulation. The labelling of the non-terminal nodes is crucial if we want rules to refer to such nodes, as, for example, a rule spreading the place node of an obstruent to a preceding nasal. Similarly, we can now also represent single segments which are complex in the sense that they require two non-terminal nodes of the same type.

To make the overview complete let us add a brief note on the relation between the segmental trees, as in (5), and syllabic structure, which, as will be familiar, is built on top of the segmental structure. In most current work the root node is NOT identified with the terminal nodes of the syllabic tree structure. Rather, root nodes are associated to so-called skeletal positions, as in (8):

(8)



syllable tree

skeletal positions (syllable terminals)

root nodes (top node of segmental tree) segmental trees

The skeleton and its relation to the segmental tree will be discussed more fully in section 3.

Summarising this section, we have seen that a major difference between SPE and current versions of autosegmental phonology involves the idea that there is a rather rich segment-internal structure, in which segments take the form of a feature tree. Information of the same type is ordered (i.e. [+ nas] [− nas]) but for the rest only dominance relations are encoded. In this respect segment-internal structure shares a fundamental property with suprasegmental, i.e. syllabic and higher-order structures, which by current insight also involve a richly articulated tree structure. In the latter domain, as is familiar, constituents are also "headed", i.e. every constituent is seen as the projection of one of its daughters. On this view, constituents consist of a HEAD and other elements which are GOVERNED by the head, or are DEPENDENT on it. This insight provides the basis for what is called METRICAL PHONOLOGY, and, of course, DEPENDENCY PHONOLOGY. Dependency relations presuppose constituency, but constituency does not imply linear order. Hence, given that intrasegmental structure is also hierarchical, dependency relations could in principle also be defined over sets of features, or sets of class nodes. In the next section we will go into this, showing that dependency relations can play an important role in segmental phonology, too.

The structures represented so far come close to what is now actually proposed by various linguists, although it is fair to say that a number of aspects are still under serious debate. In the next section, we will go into these matters in some detail, focusing on the FORM of the segmental trees, but, where necessary, discussing the CONTENT (i.e. the actual features) as well. The discussion will lead us through a sizeable list of proposals and counterproposals, and inevitably leads to the impression that there is little agreement in the field of "geometrical phonology" at present. In what follows we will limit ourselves to giving a critical survey of the various proposals that are found in the current literature.

1.2. A Review of Specific Proposals on Feature Hierarchitecture

Throughout the recent literature there is a general consensus that the set of phonological features should be split up into various sub-groupings, and that these sub-groups, which were already recognised in the SPE-system ("major class features", "tongue-body features", "manner features") but which had no formal status there, should be part of the representation of segments. Precisely how this cutting-up should be executed is a matter of serious disagreement, however, as the discussion in this section will show. The section will be opened by a discussion of the featural hierarchy propounded in the theoretical framework of Dependency Phonology in 1.2.1. Next, in 1.2.2, we will turn to an apparently independent line of work represented in particular by Clements (1985), Halle (1986), Sagey (1986) and much related work. In this section, too, we will present a number of arguments that lay bare some inadequacies of many of the proposed feature geometries. Section 1.2.3 will finally offer a short summary of the main findings. Throughout our discussion of featural hierarchitecture we will ignore as much as possible the issue of what the arity of the phonological primes should be. It is to this matter that section 2 will be devoted.

1.2.1. Dependency Phonology

In Dependency Phonology (DP) the relevance of feature grouping has long been recognised. Already in Lass & Anderson (1975) and Lass (1976) a number of specific arguments are put forward that support the view that the matrix characterising the segment should be split up into at least two submatrices, or GESTURES, the phonatory and articulatory gestures of Lass & Anderson (1975), or the laryngeal and oral gestures of Lass (1976). This subdivision into phonatory/laryngeal and articulatory/oral feature sets reflects the fact that phonological rules and processes can refer precisely to (e.g., delete) either of these gestures, the other gesture being unaffected (the so-called "stability effects"). Thus Lass (1976) discusses cases of reductions of full consonants to the glottal consonants [h] and glottal stop, [ʔ], as occurring for instance in many varieties of Scots (cf. also Lass 1984:113-5), which show the independence of the laryngeal features vis-à-vis the oral features. Apart from revealing the relevance of separate gestures for these two sets of features, these consonant de-oralisation phenomena also bear out the difference between the proposals about feature hierarchitecture made by Lass & Anderson (1975) and Lass (1976), a difference that hinges upon the status assigned to the feature [continuant], as Anderson & Ewen (1987:140-41) have pointed out. Lass & Anderson look upon this feature as part of their phonatory gesture. Thus on the basis of their feature-hierarchical model, the consonant reductions mentioned above entail the deletion of the entire articulatory gesture containing the oral tract features, but not [cont]. The result of de-oralisation of a voiceless stop is then correctly predicted to be a [–cont] segment lacking all articulatory features: [ʔ]. Lass (1976), on the other hand, assigns [cont] to the oral gesture. Hence, if voiceless stop de-oralisation were to entail deletion of the laryngeal gesture under Lass's assumptions, the fact that [ʔ] rather than [h] results would remain unaccounted for, since [–cont] would be deleted as well. Lass's (1976) description of the de-oralisation phenomena reducing voiceless stops to [ʔ] hence involves a "gesture-shift" copying the feature [–cont] from the oral to the laryngeal gesture, with subsequent deletion of the oral gesture. Subsequent discussion will reveal that the status of the feature [continuant] is problematic in the other feature geometries that we will discuss, too. Yet, however the details may be arranged, it is clear that the consonant reductions discussed above provide strong motivation for a formal distinction between oral and laryngeal features. It is these two gestures which, together with the newly introduced tonological gesture, are the primary ingredients of the most recent DP feature tree, defended in Anderson & Ewen (1987), and represented in (9).[1]

(9)

- segment
  - categorial gesture
    - phonatory subgesture
    - initiatory subgesture
  - articulatory gesture
    - locational subgesture
    - oro-nasal subgesture
  - tonological gesture

We are not going to be concerned here with the content and internal structure of the tonological gesture (cf. Anderson & Ewen 1987: sect. 7.5), except to note a correspondence on this score with Archangeli & Pulleyblank's (in prep.) featural hierarchy, in which the tonal node is also set apart from all the other nodes. We will come back to their proposals concerning the geometry of phonological features in section 1.2.2.

Let us now have a look at the content of the four subgestures. To start off with the CATEGORIAL GESTURE, the PHONATORY SUBGESTURE contains the features, or, to use DP's terminology, components |V| ("relative periodicity") and |C| ("periodic energy reduction"), which are used to specify whether a particular segment is a vowel or a consonant or "something in between". All major segment classes can be defined with the aid of (combinations of) these two components, given the concept of dependency, which gives DP its name. In DP, features can not only be joined by simple, symmetrical combination, but they can also enter into a relationship in which either component is more important, the other component being dependent on it. In addition, two components can even entertain a relation in which neither feature is dominant, a relationship which DP call "mutual/bilateral dependency". Thus we arrive at the set of dependency relationships in (10).[2]

(10) Dependency: $\{|X;Y|\}$ or $\{|X \Rightarrow Y|\}$ – Y is dependent on X
$\{|Y;X|\}$ or $\{|Y \Rightarrow X|\}$ – X is dependent on Y
$\{|X{:}Y|\}$ or $\{|X \Leftrightarrow Y|\}$ – X and Y are mutually dependent

These dependency relations hand DP the tools to express all major segment classes in terms of combinations of |V| and |C|, as in (11), which reflects the sonority hierarchy in DP terms.

(11)

```
                {|V:C|}
               / -V fric \
      {|C|}                  {|V:C⇒V|} - {|V⇒C|} - {|V⇒V:C|} - {|V|}
    -V stop \              /  +V fric     nasal      liquid      vowel
                {|C⇒V|}
                +V stop
```

In a SPE type of feature system, in order to characterise the same segment classes we would need the features [voice], [consonantal], [continuant] and [sonorant]. The last three of these are features that will be shown to play an important role in the hierarchitecture of phonological features, since it seems that outside DP, any slight consensus about the precise place of these features in the feature hierarchy is lacking (cf. also the discussion above on Lass & Anderson (1975) vs. Lass (1976) with respect to [cont]). Notice, incidentally, that DP uses two single-valued features, |C| and |V| and their interdependencies, where SPE would employ four binary features.

The INITIATORY SUBGESTURE contains the "glottal opening" component |O| and the components used for the description of different types of airstream mechanisms, |G| (for "glottalicness") and |K| (for "velaric suction"). These three components can each enter into a dependency relation with a component or a combination of the two components of the phonatory subgesture, as in (12), in which the contrast between aspirated and unaspirated voiceless stops is represented in Dependency terms (cf. Ewen 1980:9.4; Ewen 1986:204).

(12) a.

```
 |O|
  |
 |C|

[pʰ  tʰ  kʰ]
```

b.

```
 |C|
  |
 |O|

[p  t  k]
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What we see in (12) is that within a gesture representations of the two subgestures can display dependency relations. A similar relationship can also be observed between the |G| component of the initiatory subgesture and the |C| of the phonatory subgesture, used to differentiate between glottalic ingressive ({|C;G|}) and egressive ({|G;C|}) sounds, and between the nasality component |n| and the features of the locational subgesture (cf. the Chinantec nasalisation cases in (15), below). So, in addition to dependency between individual components, we have dependency between representations of subgestures belonging to the same gesture. Yet the possibility of components of the initiatory and phonatory subgestures entering into a dependency relationship is not exploited to the full: while it is apparently necessary for |O| and |G| to be able to entertain dependency relations with |C|, |K| cannot "look beyond" the initiatory subgesture, there being no DP representations in which (combinations of) |C| and |V| entertain non-symmetrical relations with |K| alone. In addition, intra-subgestural relationships are not exhaustively employed either, since we do not find dependency relations between the features contained in the initiatory subgesture. Finally it should be noted that there are no dependency relationships between the two main gestures: there are no circumstances under which segment-types are distinguished by means of a difference in the dependency relation holding between the components of the categorial and articulatory gestures. Schematically, all this is summarised in (13).

(13)

CATEGORIAL ←—*—→ ARTICULATORY

PHONATORY ←→ INITIATORY　　ORO-NASAL ←→ LOCATIONAL

|V| ←→ |C|　　|O| ←*→ |G| ←*→ |K|　　|n|　　|i| ←→ |u| ←→ |a| etc.

*

It is unclear why we find precisely the dependencies illustrated in (13). With the introduction of the notion of "intergestural dependency" (e.g. between |O| and |C|) the DP system should in principle also allow for dependency relations between (combinations of) components under the main gestures, but no such dependencies appear to be of any use.

This calls into question the concept of "intergestural dependency" a concept which Davenport & Staun (1986) have recently argued to be dispensable once the glottal opening component |O| is assigned to the phonatory subgesture and a new component |I| ("initiator velocity", expressing the direction of airflow) is assigned to the initiatory subgesture. Such a move may be advantageous from a different perspective as well. Notice that if we place |O| – which, as Anderson & Ewen (1987:145) have noted, corresponds to Halle & Stevens' (1971) binary-feature pair [spread glottis]/[constricted glottis] – in the initiatory subgesture, as in standard DP, then the phonatory subgesture contains only one phonation type, voicing, expressed by the |V| and |C| components, equivalent to Halle & Stevens' (1971) features [slack vocal cords] and [stiff vocal cords], respectively. Other glottal states, such as aspiration, creaky voice and breathy voice, must then be described with the aid of the |O| component from the initiatory subgesture, which must enter into a dependency relationship with either, or both members of the phonatory subgesture. In the standard DP system, then, the glottal states [voice] and [glottal opening], though clearly closely related, are spread across two different subgestures. Davenport & Staun's (1986) proposal to transfer |O| to the phonatory subgesture would bring the two components expressing glottal states closer together. Given the format of the present article, however, we will not go into Davenport & Staun's (1986) modifications of the DP framework in any further detail, and limit ourselves to a discussion of "standard" Dependency Phonology, as in Anderson & Ewen (1987).

Now let us turn to the daughters of the ARTICULATORY GESTURE. They are the LOCATIONAL SUBGESTURE and the ORO-NASAL SUBGESTURE. To the former obviously belong all the place features or components, listed in (14).

(14) DP place features

vocalic:	consonantal:
| i | "palatality, acuteness/sharpness"	| l | "linguality"
| u | "roundness, gravity/flatness"	| t | "apicality"
| a | "lowness, sonority"	| d | "dentality"
| ə | "centrality"	| r | "retracted tongue root"
| α | "Advanced Tongue Root (ATR)"	| λ | "laterality"

It is irrelevant for our present purposes to ask why Dependency Phonology uses precisely these components for the representation of the place of articulation of the vowels and consonants. We refer to Anderson & Ewen (1987: chapter 6) for details on the consonantal features, and to section 2.2 of the present article for a detailed discussion of DP's vocalic components in comparison with some other single-valued feature frameworks. (We also refer to Smith this vol. for a proposal concerning single-valued consonantal features that differs from the system of DP.)

Then, finally, there is the ORO-NASAL SUBGESTURE, which contains precisely one component, |n|, for "nasality". One might wonder whether DP really needs a nasality component, or, if it turns out that such a component is necessary, whether this component should have a subgesture entirely for itself. With respect to the first question it is clear that we do not need to introduce |n| for the representation of nasal consonants: these can appropriately be characterised by means of a combination of the two components of the phonatory subgesture, {|C⇒V|}, as appears from (11), above. However, nasal consonants not only form a natural class with other sonorant consonants by sharing certain characteristics in their categorial (particularly phonatory) representations, they also form a natural class with nasalised segments, which may have different specifications in the categorial gesture. In order for this latter natural class to be reflected by the DP representations of the segments in question, Dependency Phonologists argue that we need a separate component, |n|.

It is claimed that there is at least one language in which the nasality component shows dependency relations with components of the locational subgesture, viz. Chinantec (cf. Ladefoged 1971:34; Catford 1977:138). In this language there appears to be a distinction between two different degrees of nasalisation, to be represented in DP terms as in (15) (cf. Anderson & Ewen 1987:250).[3]

(15) |a| |a| |n|
              | |
              |n| |a|
        /a/   /ã/   /ã̃/

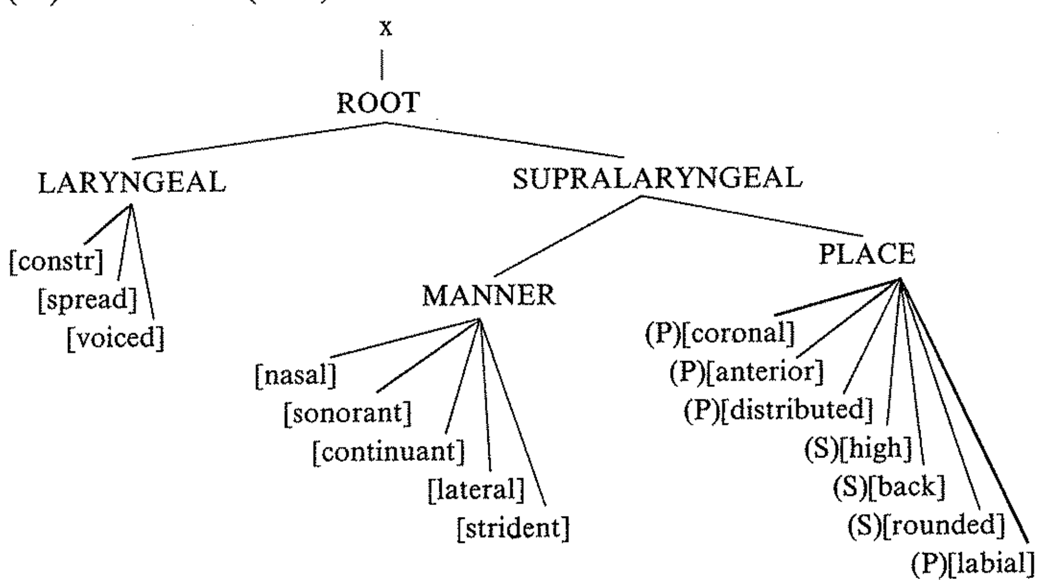
The second question, whether the nasality component or feature should occupy a (sub)gesture of its own, is rather more difficult to find support for. Although there is abundant evidence to suggest that |n|, or [nasal], can spread autosegmentally, and can hence function independently of other components or features, this does not in itself suggest that |n| should occupy its own (sub)gesture. Since the oro-nasal subgesture dominates precisely one component, it is impossible to make out on empirical grounds whether, in a case of nasal harmony, it is the oro-nasal subgesture that spreads or rather the |n| component individually: in either case we derive the same result. Hence some other argument should be found that could support the relevance of the oro-nasal subgesture. In Dependency Phonology, phonetic considerations have always played a central role in the justification and motivation of its primitives and hierarchical organisations. Although Catford (1977) recognises only three functional components in the specification of speech (correlating with DP's phonatory, initiatory and locational subgestures), Ladefoged (1971) distinguishes four processes required in speech specification. Ladefoged adds the oro-nasal process to Catford's three components. On the basis of Ladefoged's subclassification into four processes, Anderson & Ewen (1987: 148) conclude that "it seems possible, then, to account for the oro-nasal process as a distinct sub-gesture within the articulatory gesture" and that hence a subdivision into two subgestures, just as in the categorial gesture, "is perhaps not inappropriate for the articulatory gesture". Notice, though, that the motivation for a separate oro-nasal subgesture does not appear to be overwhelming.

A final question that comes up is why, in the tree in (9), the oro-nasal subgesture should be grouped together with the locational features under the articulatory gesture. Intuitively, this assumption makes sense in that the feature [nasal] can only apply to place of articulation features, and cannot have scope over the laryngeal features grouped under the categorial gesture. Yet there does not appear to be any phonological evidence from the area of assimilation processes that could corroborate or disconfirm the constituenthood of the velic and locational features.

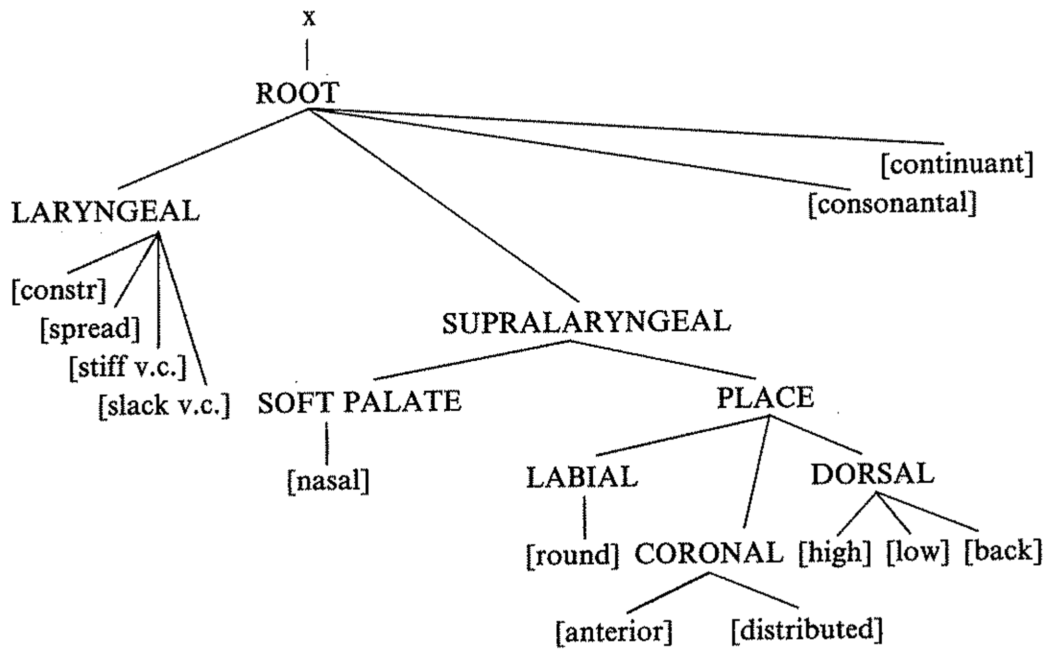
1.2.2. Binary-feature hierarchies: More grouping, no dependency

To the best of our knowledge, the hierarchical tradition in binary-feature frameworks starts with Thráinsson (1978), who proposed a distinction between laryngeal and supralaryngeal features, parallel to the original main split in Dependency Phonology into articulatory and laryngeal features (cf. 1.2.1). Later proposals are found in Mascaró (1983) and Mohanan (1983), the latter arguing for an organisation of the phonological primes into the sub-groups [phonation], [sonority] and [place], which was subsequently replaced in Clements (1985) by his rather more articulated feature hierarchy in (16), below. This hierarchy was elaborated even further by Halle (1986), Ladefoged & Maddieson (1986), and, in particular, by Sagey (1986), whose hierarchitecture is reproduced in (17).[4] The substantial differences between these two trees are, up to a certain extent, due to the fact that Clements argues that the way in which features are to be geometrically organised "depends upon phonological, rather than physiological criteria" (1985:240), while Sagey's hierarchy, just like that of Dependency Phonology, is firmly grounded in phonetic and physiological facts.

(16) Clements (1985)



(17) Sagey (1986)



Before turning to the details about the differences between (16) and (17), however, let us first note the similarities between the two trees. Both trees recognise the relevance of a place node, to which we will turn in section 1.2.2.2, and in both trees there is a primary division into a laryngeal node and a supralaryngeal node, a split-up that is recognised by virtually any theory of featural hierarchitecture, and for which we have already pointed out some corroborating evidence in our discussion of the DP feature tree. Thráinsson's (1978) well-known example in favour of this division is Icelandic preaspiration, in which the underlying geminated aspirated stops, like $/p^hp^h/$, are realised as preaspirated non-geminates, [hp]. This process, which is similar to the consonant reduction processes of Lass (1976) (cf. 1.2.1), can be analysed in terms of the deletion of the supralaryngeal features of the first member of the geminate.

A different type of example, substantiating the laryngeal/supralaryngeal split, is provided by Steriade (1987a), who points to processes of trans-laryngeal harmony, whereby a vowel assimilates to another vowel across only /h/ and glottal stop. She observes that one of the defining properties of this harmony process is that it is always a multiple-feature harmony, which leads her to assume that translaryngeal harmony involves auto-segmental spreading of a supralaryngeal node. The fact that /h/ and /ʔ/ are precisely the only consonants that do not block this process can then be explained on the basis of the fact that these segments are represented solely in terms of laryngeal features: they lack a supralaryngeal node and are hence by their very nature transparent to supralaryngeal harmony.

One final example in favour of the distinction between laryngeal and supra-laryngeal features concerns the Klamath assimilations in (18).

(18)	nl	→	ll	
	nL	→	lh	([L] = voiceless l)
	nl'	→	lʔ	([l'] = glottalised l; [ʔ] = glottal stop)
	lL	→	lh	
	ll'	→	lʔ	

← lat

lat "moves" one point left pushing away sl1 and leaving behind lar feat

According to Clements these processes entail the following. First, the supralaryngeal features of the second segment are spread backwards onto the preceding nasal or lateral, with the consequence that the supralaryngeal specifications of this preceding consonant are delinked, and secondly the supralaryngeal features of the voiceless or glottalised lateral are dissociated or delinked. To be noted here is that, as a result of this process, a voiceless /l/ turns into [h] while a glottalised /l/ leaves behind its counterpart lacking supralaryngeal specifications: [ʔ]. The relevance of the opposition laryngeal vs. supralaryngeal seems well attested, therefore. This is more than we can say for the other aspects of the trees in (16) and (17), as the subsequent discussion will show. In what follows, we will take Clements' (1985) subdivision into manner and place features as our point of departure.

1.2.2.1. Manner Features

For Sagey (1986) the processes in Klamath summed up in (18) give some evidence for her decision to attach the soft palate node (under which the feature [nasal] resides) under the supralaryngeal node, and not on the root node together with [continuant] and [consonantal]. This is so because the feature [nasal] must be removed from the leftmost segment of the pairs in (18). So a node must be spread which at least comprises the feature [nasal], for otherwise [nasal] would not be delinked, and a nasalised lateral would result. This does not mean, of course, that the soft palate node must be attached to the supralaryngeal node: it might as well be linked to the place node, for instance. What the Klamath assimilations do show, however, is that the soft palate node cannot be attached anywhere higher than the spreading node, i.e. the supralaryngeal node.

The same conclusion can be drawn on the basis of (18) with respect to the feature [lateral], which Sagey (1986) does not include in her hierarchy in (17). In her chapter 4 she briefly remarks on the place of this feature. She concludes there that although [lat] has traditionally been supposed to apply only to coronals (cf. e.g. SPE) this is not correct, since, as Ken Hale has pointed out, in Zulu and many New Guinean languages [lat] may apply to dorsals as well (cf. Ladefoged & Maddieson 1986). Lass (1984:88) has observed furthermore that many English dialects have velar laterals without any activity of the blade of the tongue, and that some Caucasian languages have velar lateral affricates and ejectives. So [lat] cannot be inserted under the coronal node, as in Halle (1986) and Steriade (1986), for otherwise it would be unable to apply to dorsals.[5] Sagey concludes that [lat] should be represented under either the place node, the supralaryngeal node or the root node. This last option seems to be untenable in view of the Klamath examples in (18), since, as we pointed out above, these examples cannot involve spreading of the root node.[6]

As we have seen in our discussion of DP in 1.2.1 the existence and relevance of a separate oro-nasal subgesture is rather weakly underpinned there. Sagey (1986) also admits that she knows of no examples that could bear out the relevance of her soft-palate node. This is due in particular, of course, to the fact that this node dominates only the feature [nasal], so that no empirical distinction exists between spreading the soft palate node or just the feature [nasal]. Nevertheless, Sagey adds, "I will maintain the hypothesis that there exists a class node for the soft palate articulator" (1986:47). Apparently, then, neither Sagey nor Dependency Phonology has succeeded in adducing any motivation for a soft-palate node or oro-nasal subgesture. Thus it is in principle possible to treat the feature [nasal] in the same way as the features [continuant] and [consonantal] in Sagey's tree in (17), by attaching this feature directly to some node without assigning it first to a class node of its own.

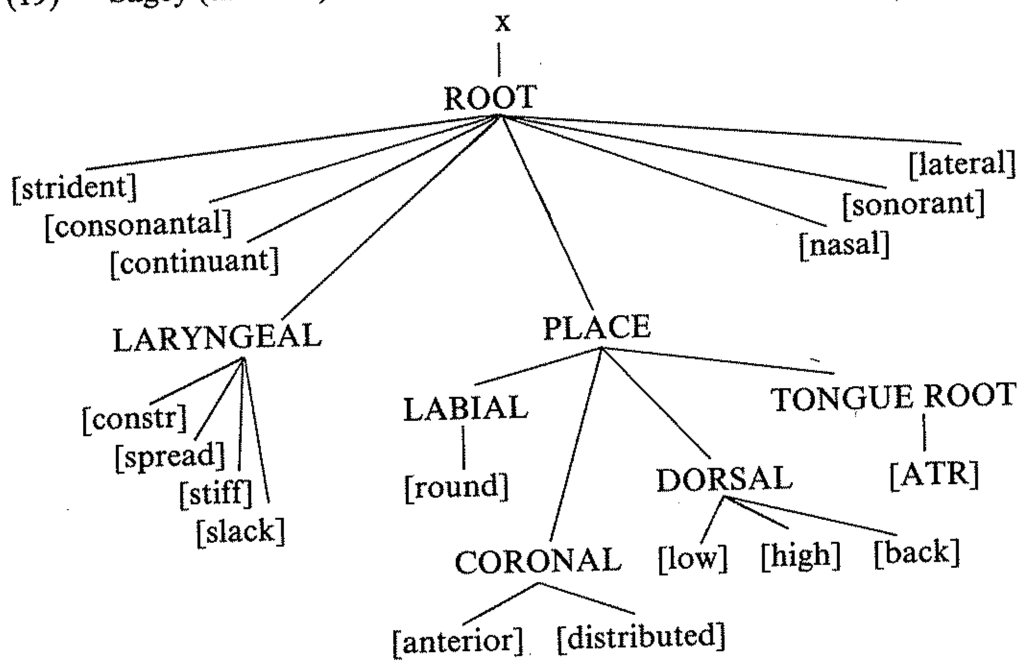
In attaching the manner features [continuant] and [consonantal] directly to the root node, and not to a separate manner node first, Sagey (1986) goes one step further than Clements (1985), who admits that "there is very little evidence to suggest that the manner tier itself functions as a unit" (1985:237), but who nevertheless still tentatively postulates such a class node in his tree in (16). He does so with the proviso that if future research should fail to adduce empirical motivation for a separate manner node the manner features should be linked directly to the supralaryngeal node. Sagey, on the other hand, chooses to lump the degree of closure features [continuant] and [consonantal] together under the root node, a decision to which we will return later on. Of the other features that Clements joins together under his manner tier, Sagey had already decided to assign [nasal] its own soft palate class node, while she leaves the status of the feature [lateral] undetermined, as we saw above. Thus we are left with [sonorant] and [strident]. With respect to the former Sagey (1986) observes that this feature corresponds to a disjunction of properties, and that it should not be represented with [cont] and [cons] on the root node, as has been proposed by e.g. McCarthy (1985), Schein & Steriade (1986) and Mester (1986) (cf. also Sagey this vol. as discussed below). Where this feature should be attached remains a moot point, however. As to [strident], which, according to Lass (1984:89), is "a leftover from the

Jakobsonian framework", Sagey remarks that this feature clearly refers to "certain acoustic properties" (1986:280), and closes the discussion there.[7,8]

It is precisely in the area of the "manner" features [nasal], [lateral], [strident] and [sonorant] that the feature tree of Sagey (this vol.) differs crucially from the hierarchy propounded in her dissertation. In Sagey (this vol.) the features [lateral], [sonorant] and [strident] are included in the feature hierarchy. Sagey chooses to treat these features in the same way as [consonantal] and [continuant] were treated in Sagey (1986), so by attaching them to the root node directly, although she does not comment on this decision. A similar view is held with respect to the feature [nasal]. Sagey (this vol.) abandons the soft palate node of Sagey (1986), a node for which – as we pointed out above – there is little evidence. In addition the feature [nasal] is "promoted" to the root node (cf. Piggott this vol.), just like all the other features joined together under Clements' (1985) manner node. Thus by gathering the manner features [consonantal], [continuant], [lateral], [nasal], [sonorant] and [strident] under the same node, Sagey (this vol.) in a sense returns to the position taken by Clements (1985), by grouping all these features together. She differs from Clements in that she does not assign these features a common class node, a decision that was already anticipated by Clements himself, and in that she attaches them higher up in the tree.[9,10]

Notice that, with Sagey's (this vol.) decision to assign the feature [nasal] and the other manner features to the root node, the supralaryngeal node of Clements (1985) and Sagey (1986) comes to dominate only the place node, and hence loses its relevance as a separate class node. This is why such a node is no longer included in the feature hierarchy proposed in Sagey (this vol.), which is represented in (19). (Attaching the manner features on two sides of the laryngeal and place nodes has no significance.)

(19) Sagey (this vol.)



Summing up the discussion so far, we cannot but conclude that the manner features are "moved around" in the feature tree without a lot of specific motivation. Clear-cut motives against attaching in particular the features [lateral] and [nasal] to the root node (cf. the Klamath assimilations in (18)) are not explicitly discussed. The status and location of the feature [strident] remains altogether unsettled, not in the least because its use is far from clear. As regards [continuant], [consonantal] and [sonorant], the impression emerges that, in spite of some differences of opinion, the former two, and probably also the feature [sonorant], should be linked to the root node, although specific argumentation for this view remains on the whole fairly implicit.

Yet there is one conspicuous exception to this view on [cont], [cons] and [son] that is worthy of notice here. In Halle (1986:22) it is suggested – albeit rather tentatively – that these three features are best specified on the place node, in particular because these features are used primarily in connection with the features joined together under this place node, and do not directly affect the laryngeal features or the feature [nasal]. Thus, on the assumption that features should be placed in the featural hierarchy in accordance with their scope relative to the other features, Halle proposes to attach [continuant], [consonantal] and [sonorant] to the place node.

Given Halle's suggestion concerning the degree of closure features, one would predict that place assimilation would automatically imply degree of closure assimilation. That this prediction is incorrect, however, appears for instance from the optional assimilation process in Sanskrit illustrated in (20) (Steriade 1982:61; Schein & Steriade 1986:722).

(20)	divas "god-GENsg" putras "son"	→	divaɸ putrah
	Nalas kamam "at will"	→	Nalax kamam

In this process /s/ optionally assimilates in place to a following obstruent, regardless of what the place features of the following segment are. Hence the process in (20) cannot just be spreading of, say, the coronal node, or the labial node. Thus only one possibility remains: (20) must involve spreading of the place node. As the manner features are not affected by the assimilation, /s/ remaining [+ continuant] irrespective of the degree of closure of the following obstruent, we conclude that they must be hierarchically higher than the place node, contrary to Halle's (1986) suggestion.[11]

Nonetheless there is still a way in which the close relationship between the features [cont], [cons] and [son] to the place features can be given formal recognition in the tree is by attaching them to a node that exclusively comprises them plus the place node. A proposal to this effect (limited to the feature [continuant]) has in fact been made in the recent literature, by Clements (1987c). He suggests that for an adequate description of the phenomenon of intrusive stops, as in the English words *dense*, *false* etc., which are pronounced by some speakers as *den[t]se*, *fal[t]se*, one should distinguish a separate *oral cavity* node, comprising the feature [cont] and the place node. On that view, the intrusive stop phenomenon can be described in terms of the rightward spreading of the nasal/liquid's oral cavity node, so that the [–cont] nature of the intrusive stop follows immediately, given that the nasal/liquid is also [–cont]. Notice, however, that the feature [son], which Halle (1986) claims to have just as close a relation with the place node as does [cont], in any event cannot be joined to the oral cavity node, since then we would wrongly predict the output of oral cavity node spreading in the case of English intrusive stops to be a [+son] segment. The feature [sonorant], then, will have to be attached higher up in the tree.

1.2.2.2. Place Features

In the previous subsection we encountered two arguments, from Sagey (1986), in favour of a separate place node. The relevance of the place node is also recognised by Clements (1985), who adduces the case of coronal assimilation in English, reflected in (21), in support of this node.

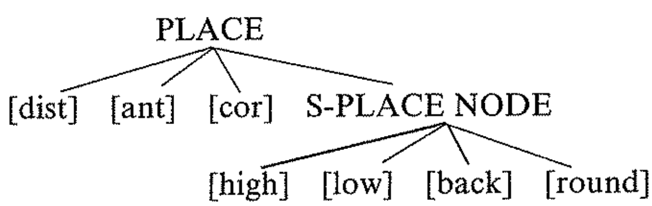
(21)		[t]	[d]	[n]
	– θ	eighth	hundredth	tenth, enthuse
	– š,ž	each, cheer	edge, gem	inch, hinge, insure
	– r	tree	dream	enrol

In English, [t,d,n] assimilate to the place of articulation of a following coronal consonant. Thus [t,d,n] are interdental before [θ], postalveolar before [š,ž], and retroflex before [r]. Halle (1986) has argued, however, that these examples should not be treated in terms of spreading of the place node, but rather as spreading of the coronal node, as Sagey (1986) has also pointed out. If these were cases of spreading of the entire place node, there would be no explanation for why this assimilation process is only triggered by coronals. Such an explanation is of course immediately available once one analyses the assimilations in (21) as cases of spreading of the coronal node.[12] Clements (1985), whose place tier largely lacks internal structure, does not have such a node. Sagey does, and has now found empirical support for this coronal node.[13]

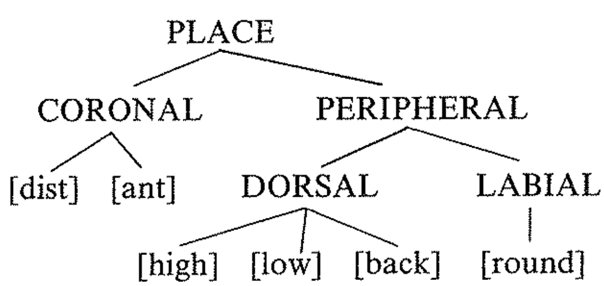
Apart from the coronal node, Sagey (1986) distinguishes two other independent class nodes internal to her place node: the dorsal and labial nodes. In Sagey (this vol.) (cf. (19)) a fourth node is added to these nodes, the tongue root node, under which the feature [ATR], which was not included in the hierarchy of Sagey (1986), is attached. Thus we arrive at a place node with an articulate internal structure, similar in essence to the proposals for internal organisation of the place features found in Halle (1986; 1988) and Ladefoged & Maddieson (1986). For the coronal node we have already found empirical support. The dorsal node comprises the place features that are primarily relevant for vowels (cf. Clements' S(econdary)-place features), but it does not contain all the features that are used for vowels: the features for lip-rounding, [round], and Advanced Tongue Root (ATR) are placed by Sagey (this vol.) on independent class nodes, the labial node and the tongue root node. Sagey points out, in support of the labial node, which is common to labial consonants and rounded vowels, that a particular harmony type, usually referred to as "rounding harmony" can be triggered by both classes of segments, as for instance in Tulu (cf. Sagey 1986:136-8). Hence not only rounded vowels, but also labial consonants like /p,m/, whose articulation does not involve lip-rounding at all, can be the triggers of "rounding harmony" which is now more appropriately referred to as "labial harmony". In a harmony system in which /p,m/ trigger labial harmony, just like /u,o/ etc., this harmony process can be described in terms of spreading of the labial node, which hence seems well motivated in Sagey's feature hierarchy. For the tongue root node no specific arguments are put forward in Sagey (this vol.), but given that tongue root advancing involves an articulator different from the tongue-body, tongue-front or lips, the tongue root articulator node has initial plausibility.

At the end of this subsection we discuss a possible motive for adopting yet another layer of hierarchical structure internal to the place node. This motivation comes from the fact that the place node dominates features that are primarily used in the description of vowels ([high]/[low], [back], [ATR], [round]) and consonants ([anterior], [distributed], plus the class nodes [coronal], [dorsal] and [labial]), two feature sets which are virtually entirely disjoint in their application. In an SPE-type of feature framework consonants only take the typical vowel features to mark secondary articulation (rounded or palatalised) or to distinguish between velars, uvulars and pharyngeals (which are all [– coronal, – anterior]), while vowels are generally exhaustively characterised with the aid of the features now under the dorsal, labial and tongue root nodes, with the exception of the rare "retroflex" vowels of certain Dravidian languages and English, for which a coronal specification is required (cf. Clements 1985:240; Halle 1986:21). Although this disjunction between consonantal (P-place) and vocalic (S-place) features is recognised by Clements (1985), he decides to "leave open the question of whether they form two new class nodes of their own, or directly link to the place tier" (1985:241). Archangeli & Pulleyblank (in prep.), who, incorrectly, claim that Clements does adopt separate P-place and S-place nodes, do assign formal status to this distinction. While continuing to link the consonantal place features directly to the place node, they postulate an independent S-place node for the set of vocalic place features, as reflected by (22). This proposal bears a resemblance to the position taken by Halle (1986), who joins the dorsal and labial nodes together under the class node "peripheral", a node corresponding to the traditional Jakobsonian feature [grave]. This proposal, which is also adopted in Dogil (this vol.), is represented in (23). These two tree structures figure prominently in the discussion in the next subsection, to which we will hence defer our discussion of these trees. Whether Sagey's (this vol.) tongue root node would be contained under Halle's peripheral node in (23) will be left a moot point.[14]

(22)



(23)



Winding up the discussion of the various feature hierarchies proposed within the binary feature framework, we have seen a fair amount of unclarity or disagreement with respect to the internal organisation of the feature tree, having to do with the *choice* of features (e.g. the question as to whether [strident] should, or should not, be incorporated in the tree – Sagey (1986) vs. Sagey (this vol.); cf. also fn. 8), as well as with the details of the feature groupings. Although such a state of affairs fraught with uncertainties does not in itself argue against the feature-geometrical approach, it is definitely not a point in its favour. We would now like to turn to some direct criticism of this geometrical approach.[15]

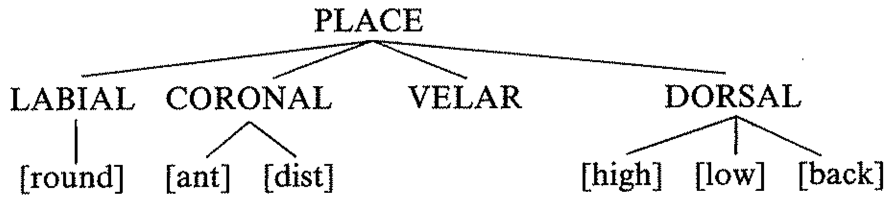
1.2.2.3. Against feature geometry: plane segregation

All the various feature hierarchitectures evaluated above can be shown to achieve considerable success in reducing all apparent cases of non-local spreading to local processes (cf. Steriade 1986, 1987a; Schein & Steriade 1986; Archangeli & Pulleyblank in prep.). McCarthy (1987) argues, however, that there are a number of problematic cases that go unexplained under this "tier segregation" approach, and which argue instead for an analysis making use of "plane segregation" introduced by McCarthy (1981), in which separate planes are linked independently to the skeleton. His criticism of feature geometry is based in particular on cases of vowel-consonant metathesis, which McCarthy wishes to analyse in terms of autosegmental spreading.

As a case in point, consider Yawelmani vowel-consonant metathesis (cf. Archangeli 1984). In this language we find – under specific but for our purposes irrelevant morphological circumstances – stem alternations like *diiyl/dyiil*, *bniit/bint* or ʔamc/ʔmaac. What is relevant with respect to this consonant-vowel metathesis effect, which is analysed by McCarthy as the spreading of the relevant features associated to the vowel across the medial consonant, is that this medial stem consonant is transparent to permutations of the stem vowel. If it is assumed, with Archangeli (1984), that the four-vowel system of Yawelmani should be analysed in terms of the features [round] and [high], the spreading node – given a feature tree à la Sagey (1986; this vol.) – would have to be the entire place node, this being the minimal node comprising both these features. Then, however, we would predict any intervening consonant to block the spreading process, contrary to fact. Even if we were to characterise the Yawelmani vowel system in terms of the tongue-body features [high] and [back], so that the spreading node could be Sagey's dorsal node, we would still wrongly predict velars, which are characterised as "dorsal", to block the spreading. A feature tree à la Sagey (1986; this vol.) hence cannot capture Yawelmani C/V metathesis in terms of spreading.

As a possible way out it might be proposed, as in Steriade (1987b), that there is a separate velar node, which is used for the characterisation of velar consonants, the dorsal node under this proposal being used for vowels only. The tree corresponding to this proposal is given in (24).[16]

(24)

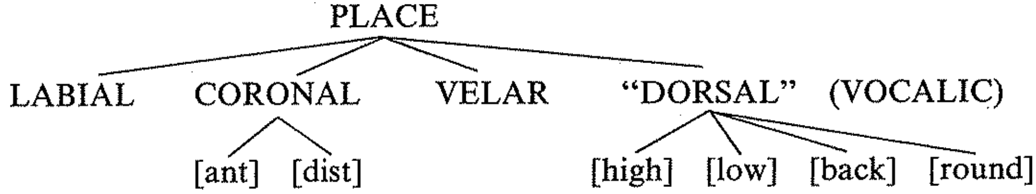


Given this feature geometry, the Yawelmani metathesis process at hand can now be analysed in terms of dorsal-node spreading *without* an intervening velar medial consonant blocking the spreading rule.

As is pointed out by McCarthy (1987:8), however, in order for this analysis to go through, it must crucially be assumed that [round] is not part of the underlying specifications of the Yawelmani vowels since otherwise this process would again have to be analysed in terms of place-node spreading, which was pointed out above to be impossible. For a language such as Yawelmani, in which rounding functions non-distinctively, a representation of the vowels making no use of the feature [round] is in itself not inconceivable. However, for languages in which rounding figures distinctively we would now predict that they can never display Yawelmani-type vowel-consonant metathesis phenomena, a prediction that can be shown to be false, since in a language like Sierra Miwok (cf. Smith 1985), which contains both a back rounded and a back unrounded vowel (/u/ vs. /ɨ/), we find a metathesis process which is to all intents and purposes similar to that in Yawelmani.

This still need not necessarily imply that a feature-geometrically based spreading approach to metathesis will not work, for one may assume that the feature [round] should not be represented under the labial node, but rather under the dorsal node (which now cannot appropriately be called "dorsal" anymore, but rather "vocalic node"; cf. the S-Place node in (22), above), as in (25).[17]

(25)



Alternatively, we may abandon the claim that each articulator be assigned its own specific class node altogether (a claim which is eroded anyway by the proposal reflected by (25) in which the articulator node representing the lips does not dominate the feature archetypally involving this articulator, and in which the "dorsal" node does not correspond to any articulator at all), and adopt a feature tree à la Archangeli & Pulleyblank (in prep.), given in (22), above, which posits a separate node for the vocalic place features, the S-Place node. Under both proposals the Sierra Miwok metathesis phenomena will be analysed in terms of the autosegmental spreading of the "dorsal"/vocalic/S-Place node. Since this node contains all and only the vocalic place features, it is predicted that consonants will never block the spreading process (unless, for some reason or other, they happen to be specified for dorsal features), as required.

The problem with these approaches, however, is that [labial] and [round] are dissociated, which is an unfortunate move in the light of the observations made by Sagey (1986) in support of her labial node (cf. the discussion of Tulu labial assimilation, which is triggered not only by rounded vowels, but also by non-rounded labial consonants like /p,m/). Moreover, it will be clear that the fact that virtually all nodes and features joined under the place node occur twice in this tree actually boils down precisely to plane segregation of vowels and consonants. It turns out, then, that C/V metathesis, if it is to be analysed in terms of autosegmental spreading, as McCarthy (1987) suggests, is incompatible with tier segregation à la Sagey (1986; this vol.).

It should be noted, however, that McCarthy's observations can only be taken as an argument against feature geometry if it is assumed that the C/V metathesis phenomena discussed by him are to be analysed in terms of spreading, rather than in terms of collapsing previously unrelated tiers. Yet the idea that C/V metathesis involves spreading does not appear to make much sense. In particular, why should one believe that one of the various C/V orderings is to be the basic order from which the other possible orderings should be derived by spreading? It would seem to us that what we are dealing with here are cases in which separate vowel and consonant melodies are associated, in various alternative ways, to a central C/V skeleton (much as in McCarthy 1981 for Arabic). Given, then, that we do not follow McCarthy (1987) in analysing C/V metathesis as involving autosegmental spreading, we dismiss his argument against feature geometry.

1.2.2.4. More evidence against tree geometry: dependency relations

In Mester (1986; this vol.) a theory is developed capturing a large number of cooccurrence restrictions and assimilations between adjacent segments in terms of the Obligatory Contour Principle (Leben 1973; Goldsmith 1976), given in (26), in conjunction with the proposal that features, or rather the tiers that they occupy, are hierarchically ordered.

(26) *The Obligatory Contour Principle (OCP)*
Adjacent autosegments on an autosegmental tier cannot be identical

Mester argues that the explanatory potential of the OCP, which McCarthy (1986) has extended from operating only as a morpheme structure constraint to applying during the derivation as well, can be exploited to the full once it is assumed that features are spread across tiers, and that these tiers in turn display dependent ordering. Put differently, Mester assumes that features, or feature tiers, entertain dependency relationships among themselves (cf. the notion "dependency" used in DP, explicated in section 1.2.1). Let us discuss now how Mester's theory of OCP-driven dependent tier ordering is compatible with the proposals of feature geometry discussed above.

As a first example of tier dependency consider the African language Alur (Northeast Congo), in which there exists the following restriction on possible root shapes (from Tucker 1969:125):

> [...] the alveolar plosives *t* and *d* and interdental plosives (written *th* and *dh*) are mutually exclusive in CVC roots, i.e. words such as *dhetho* and *thedho* are possible, as are words such as *tado* and *tato*, but roots of the type *dh-t*, *th-d*, *t-dh*, *t-th*, etc. are not. This situation exists in Luo and Shilluk as well [...]

Thus likeness for the feature [coronal] implies likeness with respect to the "secondary articulator". This can be readily explained within the framework of Mester's dependent tier ordering if it is assumed that the feature that distinguishes interdentals and alveolars, [distributed], is dependent on the primary place feature [coronal]. On this assumption it then follows, on the basis of the OCP in (26), that when two segments have identical and adjacent representations on the coronal tier, there can be only one autosegment on this tier, which must be linked to the two segmental slots in question. As a consequence, there can also be only one autosegment on the [distributed] tier, which will then automatically be associated with both segments. As an illustration, consider the examples in (27) (irrelevant details omitted).

```
(27)  a.             b.      dist      c.  *dist
                              |             |
           coronal          coronal        cor---cor---OCP
            /   \            /   \          |     |
           C  a  C          C  a  C         C  a  C
           (tat-)           (thadh-)        (*tath-)
```

Thus the likeness for the feature [distributed] of two successive coronal consonants is explained, given that [distributed] is dependent on [coronal]. Such a feature dependency is in fact reflected straightforwardly by Sagey's (1986; this vol.) feature tree, in which [distributed] is part of the coronal node. It appears, therefore, that the Alur assimilations support Sagey's featural hierarchy.

This cannot be said, however, for the assimilation processes found in the Micronesian language Ponapean, in which a distinction is made between plain labials, /p,m/, and velarised labials, [p^w,m^w], which two sets cannot be intermixed within one morpheme, as the examples in (28) show: intramorphemic multiple labials are either all plain or all velarised.

(28)	$m^w op^w$	'out of breath'
	$p^w up^w$	'to fall'
	pap	'swim'
	madep	'species of sea cucumber'

This harmony process can be captured straightforwardly on the basis of the Obligatory Contour Principle, in much the same way as in the Alur harmony phenomena discussed above, if it is assumed that the feature that characterises velarisation, [back], is hierarchically dependent on [labial]. For the sake of illustration, consider the examples in (29).

(29) a.

[back]
|
[labial]
/ \
p^w u p^w

b.

[labial]
/ \
p a p

In contrast to the Alur case, this Ponapean labial velarisation process is problematic for a feature geometry à la Sagey (1986; this vol.), if it is indeed to be captured in terms of dependency relations between the features involved, as Mester suggests. For clearly, within Sagey's feature tree [back] cannot entertain dependence relations with [labial], which is not included in Sagey's dorsal node, since dependency relations across class nodes are explicitly disallowed by Sagey (cf. also the discussion of intergestural dependency in section 1.2.1, in relation to Davenport & Staun's 1986 objection to this concept in the DP framework).

In the literature on what has come to be known as "parasitic harmony" (cf. Steriade 1981 for this term), a range of phenomena can be distinguished that exquisitely lend themselves to an account in terms of dependent tier ordering à la Mester (1986; this vol.). The difference with the examples given above, however, is that here the dependencies between the tiers involved are not fixed cross-linguistically, but differ in individual languages.

The most conspicuous case in point with respect to this parametric tier ordering is the contrast between the possibilities of cooccurrence of different root and suffix vowels in Ainu and Ngbaka, to which we will turn now.

In the Japanese language Ainu we can distinguish between two classes of roots. In one class the vowel found in the suffix is identical to the root vowel, as in (30), while in the other class the suffix vowel is a high vowel opposite in backness to the root vowel.[18] This latter class is exemplified in (31) (examples from Itô 1984).

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

(31)	hum-i	"to chop up"	mus-i	"to choke"
	pok-i	"to lower"	hop-i	"to leave behind"
	pir-u	"to wipe"	kir-u	"to alter"
	ket-u	"to rub"	rek-u	"to ring"

Thus we see that in Ainu it is possible for two successive vocalic melodies to be of equal backness *only* if the two vowels are of the same height as well. In other words, two successive vowels of like backness must be equally high (and hence fully identical). We do not find such sequences as **oCu* or **eCi*. This can be accounted for as an OCP effect, given that in Ainu the height tier is dependent upon the backness tier, as in (32).

```
(32)   [-high]  [+high]     [-high]  [+high]        [+high]
          |        |           |        |              |
      *[+back]  [+back]    *[-back]  [-back]        [-back]
          |        |           |        |             /  \
       C  V     C  V        C  V     C  V         C  V  C  V
         (*CoCu)              (*CeCi)          (CiCi, e.g. pisi 'ask')
```

Thus the OCP can account for the vowel cooccurrence restrictions found in Ainu provided that the feature specifying vowel height is taken to be dependent upon the feature for backness. Similar cooccurrence restrictions in Ngbaka, a Congo-Kordofanian language, suggest, however, that the ordering of the height and backness tiers should be reversed.

In Ngbaka, which has a standard five-vowel system with ATR-distinctions among the mid vowels, the following restrictions on vowel sequences hold in disyllabic words (Wescott 1965):

> If a disyllabic word contains /i/, it does not also contain /u/; if /e/, it does not also contain /O/, /E/, or /o/; if /u/, it does not also contain /i/; if /o/, it does not also contain /e/, /E/, or /O/; and if /O/, it does not also contain /E/, /e/, or /o/.

Thus a Ngbaka disyllabic word can contain two identical mid or high vowels, as in (33a,b), but two different mid or high vowels are disallowed (33c). As soon as the two vowels differ in height, they can freely cooccur regardless of their backness, as is shown in (33d).

(33) a. bEŋE "to cement a piece"
bOŋO "brains"
ʔele "to forget"
zoko "beautiful"
b. liki "to heat"
tulu "mushroom"
c. *beno, *benO, *bEno, *bEnO, *benE, *bOno, etc.; *liku, *luki
d. pEpu "wind"
niŋE "amusement, entertainment"
sEti "chance, luck"
gbie "field"
seti "asleep"
kOpu "cup"

Again, these cooccurrence restrictions follow naturally from the OCP given the dependent ordering of the height and back tiers displayed in (34).[19]

```
(34)   [–back]    [+back]    [–back]  [+back]         [–back]
          |          |          |        |                |
      *[+high]   [+high]    [–high]  [+high]          [+high]
          |          |          |        |               / \
       C  V   C      V       C  V   C    V         C  V   C  V
        (*CiCu)               (CECu: pEpu)           (CiCi: liki)
```

From the preceding discussion it will be clear that the features specifying vowel height and backness must be allowed to enter into dependency relations with one another, and that their relative dependency must be allowed to vary cross-linguistically. Both these demands on the features [high/low] and [back] can be realised given the feature hierarchy of Sagey (1986; this vol.), in which these two features are both part of the same node (i.e. the dorsal node) and are not assumed to entertain any intrinsic, universal hierarchical relationship within this node.[20]

The situation is different, however, when we look at another case of parametric tier ordering, also found in Ngbaka. As the reader may have noticed, it is not just the feature [back] in which two successive vowels of equal height must agree: they must also be identical with respect to the feature [ATR]. Thus, the tier occupied by [ATR] must also be assumed to be dependent on the height tier in Ngbaka. As an illustration, consider (35).

(35)			
	[–ATR] [+ATR]	[–ATR] [+ATR]	[–ATR]
	*[–high] [–high]	[–high] [+high]	[–high]
	C V C V	C V C V	C V C V
	(**bEno*)	(*pEpu*)	(*bEŋE*)

From the representations in (35) it follows straightforwardly that disharmony in ATR-ness is allowed just in case there is also disharmony in height. But in order for this to follow from the OCP, it must crucially be assumed that there is a dependency relation between [ATR] and the feature for vowel height. Such a dependency relation is inconceivable, however, if we base ourselves on the feature tree of Sagey (this vol.), in which [ATR] is taken to occupy a node of its own, the Tongue Root node. This entails that [ATR] can only entertain a dependency relation with itself, since hierarchical relationships across class nodes are not allowed, as we know. The Ngbaka examples in (35) are hence problematic for Sagey's feature hierarchy, just as the Ponapean case discussed above, if we adopt Mester's (1986; this vol.) account of the phenomena in question.

Having come back to the case of Ponapean labial velarisation at the end of the previous paragraph, let us now discuss one final example of vowel harmony, from Kirghiz (Altaic; cf. Johnson 1980, Steriade 1981), which involves, apart from the feature [high], which is irrelevant for the Ponapean case, the features [back] and [round], of which the former also figures in Ponapean labial velarisation, while the latter, [round], is – given Sagey's (1986; this vol.) tree – the daughter of the labial node, which is the head-tier in the Ponapean assimilations. In Kirghiz we find a process whereby a front rounded high vowel affects a following non-high vowel, turning it into a front rounded non-high vowel (e.g. /kül+gAn/ → [külgön], where /A/ represents a vocalic archisegment specified for height only). Steriade (1981) has shown that in the case of Kirghiz, rounding harmony is parasitic on backness harmony (cf. Van der Hulst this vol. for more details). Mester (1986), essentially following Steriade, argues that this harmonic transmission of [+round] parasitic on active backness harmony can be made sense of if it is assumed that the tier occupied by [round] is dependent on [back], and that backness harmony in Kirghiz spreads only [–back], since [–back] is the only value for this feature present in the underlying representation in Kirghiz. As an illustration, consider (36).

(36)
```
[+round]
    |
 [-back]
    |\
    | \
    |  \
    |   \
[+high] [-high]
    |       |
 k  ü  l  g  ö  n
```

What is particularly interesting about this example is the fact that [round] must be assumed to be dependent upon [back]. As we already saw earlier on, a dependency relationship between these two features is out of the question if we base ourselves upon the Sageyan feature geometry. But even more puzzling is the fact that what we see in (36) is a relation between [back] and [round] in which the latter is the dependent, while in the case of Ponapean labial velarisation (cf. (29)) [back] is dependent on [labial], the node which, in Sagey's tree, comprises the feature [round]. Thus there is a conflict between Ponapean and Kirghiz with respect to the relative dependency of [back] and [round]: if [back] is universally dependent on [labial], as in Ponapean, then [round], which according to Sagey is a daughter of [labial], is predicted never to subject [back], although it is apparently precisely that which is required to be the case in Kirghiz.[21]

With the conclusion reached at the end of the previous paragraph we can link up with one of our findings from section 1.2.2.3, where the status of the labial node, although firmly motivated by Sagey (1986), was also shown to be quite problematic, in particular once one wishes to distinguish a separate node for all vocalic place features (e.g. Archangeli & Pulleyblank's (in prep.) S-Place node, or Halle's 1986 peripheral node). It seems likely, then, that a separate labial articulator node, containing the feature [round], is untenable. It also turns out, in the light of the other observations made in the present section, that the status of most of the other articulator nodes that are part of Sagey's densely-structured place node, particularly the dorsal and tongue root nodes, is highly questionable. The interesting exception in this respect is Sagey's coronal node, against which we have not found compelling evidence. In fact, the Alur examples discussed above seem to support the relevance of such a node. This, then, may be the only articulator node that can be upheld, but this should not be surprising in the light of the fact that there has always been a feature [coronal] to begin with. Apart from this coronal node, it seems fairly clear that the place node should be left largely unstructured internally.

The discussion so far seems to indicate that, although the various attempts made in the literature to motivate some hierarchical structure internal to the place node are untenable, the part of the feature tree above the place node (apart from the manner features) is far less controversial. In particular, all trees discussed in this section distinguish at least a laryngeal node, comprising all glottal state features, this node being set apart from all supralaryngeal features (notably, the place of articulation features). Is this then a part of the feature geometry that can remain intact, or are there even here arguments that expose the unfeasibility of feature geometry in general?

Mester's (1986) theory of dependent tier ordering suggests that the "supralocational" hierarchy found in the various trees discussed above, with the glottal state features set apart from all other features, is untenable. Mester shows that tier ordering is not limited to such features as [high], [back] or [ATR], but that there is also variation in "the geometrical locus of laryngeal features and of the nasal feature. These features can be dependent on the place features ... or be directly linked to the core [i.e. the root node]." As an example, consider Javanese (cf. Uhlenbeck 1949), where there exists the following constraint on possible cooccurrences of consonants within the root:

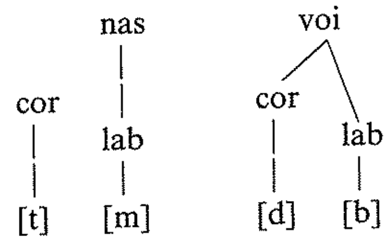
(37) *Javanese Consonant Cooccurrences*
Homorganic consonants exclude each other unless they are identical in all features (Mester 1986: 94)

Thus, two subsequent consonants with the same place of articulation must both agree in nasality/orality and voicing so that for instance *p...p* and *p...t* are allowed, while **p...b/m* is not.

These cooccurrence restrictions can be straightforwardly accounted for on the basis of Mester's (1986) framework of OCP-driven dependent tier ordering if it is assumed that, in Javanese, [nasal] and [voice] are dependent upon the place features (or on the various articulator nodes gathered under the place node, as in Sagey 1986; this vol.). Thus, consider the examples in (38) and (39).[22]

(38)
```
                                   nas          nas
             voi          voi       |            |
              |            |        |            |
  *-lab----lab--------*-lab----lab--------*-lab----lab------------------OCP
              |            |        |            |       |
    [p]      [b]          [b]      [m]          [m]     [p]
```

(39)



On the assumption that [voice] and [nasal] can be dependent on the place features, then, an elegant account can be given of the Javanese consonant cooccurrence restrictions.[23]

It should be emphasised that Mester's (1986) examples involving dependency relations between the place features and the laryngeal features or the feature [nasal] are problematic for the way in which feature geometries are generally built up. If it is correct that the laryngeal node can be dependent on the place features, this would sharply conflict with the common assumption that the laryngeal node is not contained in the place node, but is in fact hierarchically higher in the tree than the place node. The arguments presented by Mester (1986) seem to suggest, therefore, that even the part of the feature hierarchy above the place node is not unproblematic, and actually untenable if tier dependency is consistently employed. The conclusion must be, then, that even if the objections against the internal structure of the place node might be circumvented, that still will not "save" feature geometry in general, since even the hierarchical structure above the place node is irreconcilable with the facts.[24]

1.2.3. Summary

At the end of this section on featural hierarchitecture, let us sum up our findings. We started off discussing a variety of specific proposals with respect to the hierarchisation of phonological features, made within the theoretical framework of Dependency Phonology and within "traditional" binary-feature theory as well. It turned out that, particularly in the binary tradition, there is considerable disagreement on a whole range of issues. Thus, while all proposals seem to recognise the relevance of special class nodes for the laryngeal and place of articulation features, the status of the manner or degree of closure features is on the whole unclear. Motivation for a separate manner tier as in Clements' (1985) tree seems lacking, but at the same time the position of the individual features that Clements stacks under his manner node is still a matter of serious debate.

Furthermore, there is a clear sense in which all recent proposals concerning binary-feature geometry feel the need for hierarchical structure internal to the place node. Yet here as well, opinions about how precisely this internal structure should be achieved diverge greatly. Actually, it even seems to be the case, in view of Mester's (1986) theory of dependent tier ordering, that any such organisation of the place features will inevitably run into serious problems.

In view of these problems a return to the feature geometry propounded in Dependency Phonology, in which the locational subgesture is completely unstructured internally, may be attractive, although some organisation of the place features may still be conceivable. But even though the DP feature hierarchy stands up to the objections made against the various binary-feature geometries, this tree as well will not be able to face the arguments from Mester's (1986) dependent tier ordering against the hierarchisation of the laryngeal and velic features relative to the place features. The overall conclusion that presents itself at the end of this section is, then, that feature geometry finds itself in a serious crisis, and that there is no obvious way in which it can be restored.

In this section we have concentrated primarily on consonantal features, or features used for the description of consonants, in particular because the motivation for the specific hierarchies discussed here has mainly been derived from phonological processes affecting consonants. We will return to the vocalic features in section 2.3, where we will discuss and compare a number of recent unary-feature systems for vowels. First, however, we turn to the question as to what the arity of phonological features is.

2. UNDERSPECIFICATION AND PRIVATIVENESS

2.1. Background

In this section, we discuss issues regarding segmental representations which are largely independent of the subject matter of section 1. Here we focus on the formal status of the features and, in particular, on the question as to whether features are binary or unary. Most researchers have taken the point of view that all features are formally binary valued, a position strongly advocated in the early work of Jakobson, and first presented in a rigorous way in Jakobson, Fant & Halle (1952) and, somewhat modified, in Jakobson & Halle (1956). The SPE feature system is largely based on this work, different in minor ways regarding the choice or definition of features, but entirely faithful to the BINARITY HYPOTHESIS.

The notion "distinctive feature" of course predates Jakobson's binarity thesis, going back to the Prague-school concept of relevant sound properties. Due to its distinctive sound properties any segment is opposed to all other segments in a particular system. Oppositions, according to Trubetzkoy (1939), are not all of the same logical type. In particular, he makes a distinction between three types of opposition:

(40) a. *Privative opposition*
A difference in presence or absence of some property or mark
b. *Gradual opposition*
A difference in DEGREE of the same property
c. *Equipollent opposition*
A difference in presence of one property and the presence of another property, i.e. the two opposing properties are logically equivalent

Although this tripartition refers to oppositions, one might classify the set of distinctive features, representing relevant sound properties, along the same lines. Typical examples of a privative opposition involve nasality, rounding or voicing. Hence one might propose that the relevant features are privative or unary in the sense that a segment which is characterised by the property of being nasal, rounded or voiced is specified with a feature [nasal], [round] or [voice], whereas the non-nasal etc. counterpart simply lacks this feature in its representation. A typical gradual opposition involves vowel height. Hence one might argue that there is a n-ary (3- or 4-) valued feature [high]. The same could be said of tonal height differences.[25]

It is less straightforward, however, to see what an equipollent feature would be, since the examples which are given by Trubetzkoy do not necessarily involve cases where the opposition involves the two poles of a single dimension (e.g. f/k). If we restrict the notion of an equipollent opposition to cases in which a single dimension is involved, however, one could say that we have an equipollent feature when both poles must be referred to. So, for the sake of the argument, let us say that for vowels the front-back dimension involves two poles, front and back, neither of which can be treated as a privative feature. In that case a single binary feature is involved, say [back] (or [front]), for which both values ("+" and "–") have the same status. Essentially, it would seem that equipollent features are binary features for which both values have equal status.

As Trubetzkoy points out, an opposition which is logically gradual can, in a given system, function privatively. So if only two vowel heights need be distinguished, one might take a privative feature [high] (or [low]). To this one might add that it is also possible in that case to invoke an equipollent feature [+/–high]. However, one can go further than this. It is easy to see that the three types of features, privative, gradual and equipollent (or binary), can always be interchanged. Hence the choice for one or the other cannot be made on the basis of an independently motivated "logical" status of the relevant sound properties.

In support of this, we might note that a strict equipollent view is inherent to Jakobson's binarity thesis, whereas, for example, Sanders (1972) and dependency phonologists (cf. Anderson & Ewen 1987) maintain that all features are privative. Everyone claiming that at least one feature is more than single-valued adheres to the third position.

It is fair to say that most researchers using binary instead of privative features adhere to a theory of underspecification, with the result that, although formally binary, features function largely as if they were privative. Recently, Trubetzkoy's "mixed" theory has gained interest. For example, Goldsmith (1985; 1987), Steriade (1987b) and Mester & Itô (1988) argue that some features are binary whereas others are single-valued, and even that the same feature might function differently in this respect in different systems. In response to the binary dogma of SPE, Chafe (1970) already argued for a mixed system, pleading for a return to the position that features like rounding or nasality are "singulary features".

It is our personal belief that "strong privativeness" is a desirable and tenable position. It is a desirable position simply because it represents the most restrictive view. It is also a tenable view because most of the evidence pointing to some form of binarism can, contrary to claims in the literature, be analysed without making use of binary features. In addition, using binary features, even in the context of a theory of (radical) underspecification, leads to empirical overgeneration. It is beyond the scope of this article to spell out the issue at stake in full detail. We limit ourselves here to a somewhat critical discussion of underspecification theory. Then we will discuss a few single-valued feature frameworks. In both sections we limit ourselves to vocalic features.

2.2. Underspecification theory

Currently two versions of Underspecification Theory (UT) are available. In one version, which Archangeli (to appear) calls "contrastive UT" (CUT), values are left unspecified which are redundant in the sense that they can be predicted on the basis of the values of other features. Hence these values are not contrastive. The other version, "radical UT" (RUT), allows, in addition, leaving out specifications which are UNMARKED. Unmarked values can, but need not, be redundant.

In this subsection we will discuss UT, especially RUT, in some detail. Firstly, we discuss a traditional objection to underspecification concerning ternary power, showing that the objection does not necessarily hold of any theory using underspecification. Secondly, we discuss how RUT works.

2.2.1. Ternary power

Since the publications of Lightner (1963) and Stanley (1967), it has been known that allowing underspecification can give rise to ternary power, i.e. an opposition between "–", "+" and "Ø". Consider the argument, which is here presented in an autosegmental form (after Pulleyblank 1986, Dresher 1985):

(41) a. Input: Lexical representations

$$\begin{array}{ccc} {[+F]} & & {[-F]} \\ | & & | \\ A & B & C \\ | & | & | \\ \begin{bmatrix}-G\\-H\end{bmatrix} & \begin{bmatrix}-G\\-H\end{bmatrix} & \begin{bmatrix}-G\\-H\end{bmatrix}\end{array}$$

b. Phonological rules:

1. $[-G] \rightarrow [+G] \;/\; \begin{array}{c}{[+F]}\\ | \\ X \\ | \\ \_\_ \end{array}$

2. $[-H] \rightarrow [+H] \;/\; \begin{array}{c}{[-F]}\\ | \\ X \\ | \\ \_\_ \end{array}$

3. $X \rightarrow \begin{array}{c}{[-F]}\\ | \\ X\end{array}$ (default rule for [F])

c. Output: Intermediate or surface representations

$$\begin{array}{ccc} {[+F]} & {[-F]} & {[-F]} \\ | & | & | \\ A & B & C \\ | & | & | \\ \begin{bmatrix}+G\\-H\end{bmatrix} & \begin{bmatrix}-G\\-H\end{bmatrix} & \begin{bmatrix}-G\\+H\end{bmatrix}\end{array}$$

In the input A and C are distinct, but B is not distinct from either A or C. In the output, however, B is distinct from both A and C. Hence the absence of the [–F] specification on B has functioned as a third value. On the assumption that we do not want features to be ternary-valued, one conclusion could be that zeros should be forbidden, which was Stanley's (1967) conclusion. But accepting Stanley's suggestion to fully specify all matrices is unattractive because, according to proponents of underspecification theory, there are compelling arguments for not specifying predictable and default values, apart from the mere desire to keep lexical representations maximally simple.

Firstly, as argued by Ringen (1977; this vol.) and Kiparsky (1982), P-rules can be allowed to apply intra-morphemically and inter-morphemically, without the Strict Cycle Condition (SCC) having to be abandoned, if we can restrict this condition to feature-changing applications. This, however, presupposes that intra-morphemic application must be feature-filling, filling in lexically unspecified information.

Secondly, using underspecification, a principled explanation can be offered for the fact that in harmony systems, for example, a particular value of the spreading feature appears on vowels which are arguably not subject to the harmonic spreading; this is the default value. If all vowels had to be specified and both values were specified randomly, so to speak, such patterns would remain unexplained.

Thirdly, a more recent claim involves the idea that underspecification plays a crucial role in accounting for action-at-a-distance. If it can be assumed that segments in between trigger and target which are clearly "ignored" in some assimilation or dissimilation process bear no specification at the relevant tier, such apparently non-local processes can be reduced to local operations affecting adjacent feature specifications. We will not go into this point here. It will be clear, however, that this mode of explanation crucially relies on the notion underspecification.

In view of these assets of UT, Kiparsky (1982) follows a different route than Stanley (1967). He argues that if we leave out not only predictable, but also default values, only one value is specified lexically in any given environment, so that instead of having three values (+, – and Ø), we will always have at most two (only – and Ø or + and Ø). Let us, for the sake of reference, express this as a principle:

(42) *The Feature Specification Principle (FSP)*
For any feature [F] only one value can be specified in any environment E

This leads to what we have referred to as Radical UT. Pulleyblank (1986:172) argues, however, that the FSP does not prevent ternarism, because for a given feature, "+" may be the lexical value in environment P, whereas "–" is the lexical value in another (not necessarily strictly complementary) context Q. As an example, consider (43).

(43) a. Input: lexical representations

$$\begin{array}{cccc}
[+R] & & [-R] & \\
| & & | & \\
A & B & C & D \\
| & | & | & | \\
[+B] & [+B] & [-B] & [-B]
\end{array}$$

b. Default rules:

$$1.\quad [\emptyset R] \rightarrow [-R] \;/\; \begin{array}{c} \_ \\ | \\ V \\ | \\ [+B] \end{array}$$

$$2.\quad [\emptyset R] \rightarrow [+R] \;/\; \begin{array}{c} \_ \\ | \\ X \\ | \\ [-B] \end{array}$$

According to Pulleyblank the very possibility of having the representations in (43a) leads to a ternary system, as we can formulate a rule applying to [+R] vowels, which ignores vowels which are unspecified for [R] and which will become [+R] by a default rule.[26]

Archangeli & Pulleyblank (in prep.) claim that this use of zero should be ruled out, i.e. any rule referring to [+R] (case A in (43)) should also apply to case D (which has [+R] unspecified). In the example just discussed, this would imply that the default rule filling in [+R] should apply prior to the phonological rule which refers to [+R]. To make sure that this is the case, Archangeli & Pulleyblank (in prep.) formulate the following convention:

(44) *Redundancy Rule Ordering Constraint (ROC)*
A default or complement rule assigning [αF], where "α" is "+" or "–", is automatically assigned to the first component in which reference is made to [αF]

In addition, Archangeli & Pulleyblank argue that rules apply as soon as possible within the component that they belong to.[27,28]

Dresher (1985) correctly points out that the ROC alone is sufficient to also prevent all misuse of zeros, even if both values are allowed underlyingly. However, as we saw above, the argument in favour of the

FSP also has an empirical basis: free lexical specification of both values prevents the formulation of certain phonological conditions (in particular, the Strict Cycle Condition and the Locality Condition). Hence proponents of UT want to maintain the FSP, alongside the ROC.

It would seem, then, that Stanley's main objection to underspecification may well be without force. Ringen (1977) already made the same point taking a somewhat different line of reasoning (cf. Ringen, this vol.). Given some precautions, then, zero specifications need not be a threat to a binary feature system. In the next subsection, we will briefly discuss the mechanics of RUT.

2.2.2. Redundancy rules and default rules

Consider a simple vowel system as in (45):[29]

(45)

	i	u	e	o	a
high	+	+	−	−	−
low	−	−	−	−	+
back	−	+	−	+	+

This matrix contains redundant information, i.e. to distinguish /a/ from all other vowels it is sufficient to specify it only as [+low]. Such redundancy is encoded in redundancy rules of the format A → B, read "A implies B". Redundancy rules are not phonological rules. They express true statements about the feature make-up of segments in (45). Therefore, if A → B expresses a redundancy, −B → −A must be true as well (via Modus Tollendo Tollens, MTT). Hence the following redundancies hold:[30,31]

(46) a. [+low] → [−high] $\dashv\vdash$ [+high] → [−low]
b. [+low] → [+back] $\dashv\vdash$ [−back] → [−low]

c.

	i	u	e	o	a
high	+	+	−	−	
low				−	+
back	−	+	−	+	

What the matrix in (46) expresses is nothing but "traditional" underspecification; non-contrastive values are left unspecified. This is what Archangeli (to appear) calls "contrastive UT". The idea of "radical underspecification" is that we can go further than this and use only one value for each feature in any given environment. To the redundancy rules in (46), we can add the following default rules:

(47) a. [ ] → [–high]
b. [ ] → [–low]
c. [ ] → [–back]

d.

	i	u	e	o	a
high	+	+			
low					+
back		+		+	

The values which are specified would be considered the marked values in a theory à la Chomsky and Halle (1968:ch. 48), specified in terms of m's. The m/u notation, however, was used because of Stanley's argument against blanks.

Since the redundant values for [high] and [low] are the unmarked values, no harm is done if we only write the default rules. This, in any event, appears to be the practice of RUT. So the full set of rules needed is that in (49):

(48) a. [+low] → [+back]
b. [ ] → [–high]
c. [ ] → [–low]
d. [ ] → [–back]

Suppose, on the other hand, that the default values are different, such that, for instance, the default for [high] is "+":

(49) [ ] → [+high]

We then need a redundancy rule introducing predictable occurrences of [–high] as a separate statement:

(50) a. [+low] → [–high]
b. [+low] → [+back]
c. [ ] → [+high]
d. [ ] → [–low]
e. [ ] → [–back]

d.

	i	u	e	o	a
high			–	–	
low					+
back		+		+	

These two (and various other possibilities) are theoretically well-formed, according to RUT. With respect to this, Archangeli (to appear) comments:

> If such options are freely available, the learnability of a system becomes quite a challenge. Thus, some principle must be included in the theory in order to reduce the burden on simply learning the inventory. The proposal in Archangeli (1984) is that certain rules/specifications are preferred by Universal Grammar. During acquisition the first approximation will be in accord with these universal preferences and other options will be selected only if language particular evidence motivates such variation. The specifications and rules given in [(48)] are taken as a working hypothesis to be those preferred by universal grammar.

Let us proceed by looking at a somewhat more complex system, having rounded front vowels:

(51)

	i	y	u	e	ø	o	a
high	+	+	+	–	–	–	–
low	–	–	–	–	–	–	+
back	–	–	+	–	–	+	+
round	–	+	+	–	+	+	–

First, we only consider the redundancies:

(52)
a. [+low] → [–high] ┤├ [+high] → [–low]
b. [+low] → [+back] ┤├ [–back] → [–low]
c. [+low] → [–round] ┤├ [+round] → [–low]

d.

	i	y	u	e	ø	o	a
high	+	+	+	–	–	–	
low							+
back	–	–	+	–	–	+	
round	–	+	+	–	+	+	

It would seem, though, that there is a further redundancy:

(53) [+back,–low] → [+round] ┤├ [–round,–low] → [–back]
┤├ [–round,+back] → [+low]

The rules in (52) and (53) are all true of the matrix in (51). Yet, by allowing (53), we are unable to fill in the values for [low] and [round] of /e/ and /o/, however. This problem is created by the fact that the rules in (52) refer to dependencies which, albeit in a reversed form, are expressed by one of the rules in (54):

(54)	[+back, −low]	→	[+round]	⇔	[+round]	→	[−low]
	[−round, −low]	→	[−back]	⇔	[−back]	→	[−low]
	[−round, +back]	→	[+low]	⇔	[+low]	→	[+back]
					[+low]	→	[−round]

Simply adding a set of default rules will not solve the problem. So, some principle must be formulated such that we disallow the cooccurrence of these redundancy rules. We are not aware of any proposals to this effect made by proponents of RUT, but we will assume the following to hold. Above, we already saw that a default rule may render a redundancy rule superfluous. Let us now turn this into a condition:

(55) If a context-free rule introduces the value "α" for some F, any redundancy rule introducing this value is suppressed.

Proponents of RUT perhaps do not bother to specify how particular sets of fill-in rules are arrived at, because the sets are "preferred by UG" (cf. the quotation from Archangeli, to appear, given above).

Now, the default rules in (56) by themselves take out most of the redundant values:

(56) a. [ ] → [−high]
b. [ ] → [−low]
c. [ ] → [−back]
d. [ ] → [−round]

e.

	i	y	u	e	ø	o	a
high	+	+	+				
low							+
back			+			+	+
round		+	+		+	+	

These default rules and principle (55) therefore make most of the redundancy statements "redundant", but we still need (57), which, by the Elsewhere Condition, is ordered before the default rule introducing [−back]:

(57) [+back, −low] → [+round]

Because the principle in (55) suppresses a number of redundancy statements, we no longer run into the problem noted above. We end up with the following list of rules:

(58)
a. [ ] → [–low]
b. [+low] → [+back]
c. [ ] → [–back]
d. [+back, –low] → [+round]
e. [ ] → [–round]
f. [–round, +back] → [+low]
g. [ ] → [–high]

h.

	i	y	u	e	ø	o	a
high	+	+	+				
low							+
back			+			+	
round		+			+		

This matrix represents the absolute minimum of information, containing only one value for each feature, and of these only the distinctive ones. We will refer to these as the LEXICAL values. Incidentally, it is not really essential that all lexical values turn out to be "+".

Finally, consider how this works out if we have back unrounded vowels, assuming two distinctive heights. We really need no more than the rules in (59):

(59)
a. [ ] → [–high]
b. [ ] → [–back]
c. [+back] → [+round]
d. [–back] → [–round]

b.

	i	y	ɨ	u	e	ø	a	o
high	+	+	+	+				
back			+	+			+	+
round		+	–			+	–	

To avoid specifying back unrounded vowels as formally less marked than back rounded vowels, we must, in this system, mark unrounded back vowels as [–round], implying that both values of [round] are used underlyingly.

We have now outlined a version of radical underspecification theory which is reasonably faithful to proposals such as those of Archangeli (1984; to appear) and Archangeli & Pulleybank (in prep.), although we have added a proposal of our own which may be useful in determining which rules will be activated to fill in maximally underspecified matrices. This is one point where introductions to RUT supply too little information.

To conclude this section, let us briefly discuss a point made in Archangeli (to appear) regarding a difference between CUT and RUT. She claims that the feature is the most basic unit in RUT, whereas the segment is the most basic unit in CUT. She adds to this that "to the extent that a feature based theory of phonology is advocated, the result with Radical Underspecification, that features are the most basic units, is the more coherent result" (p. 53).

To illustrate this, Archangeli discusses a five vowel system as in (45). In RUT such a system results from taking the set of logically possible combinations of the *feature specifications* [–high], [+low] and [+back]:

(60)	i	u	e	o	a			
high			–	–		–	–	
low					+	+	+	+
back		+		+		+		+

Given the rules in (50), all four representations for /a/ are mapped onto the same matrix. The evaluation matrix requires that we take the first representation only, and, as a result, the inventory is derived from freely combining the elements of the feature inventory. In CUT things are different, because, as Archangeli assumes, a matrix having all and only the contrastive values can only be established by inspecting the actual inventory. Hence the segment inventory must be basic. It seems to us, however, that a matrix as in (46c), which is in accordance with CUT, results from freely combining BOTH values of all three features, giving, of course, again eight combinations. If we then assume that, just as in RUT, certain redundancy rules are simply there (unless they are suppressed), because they are preferred by UG, we get the desired reduction to just five vowels. In fact, the redundancy rules we need are those in (50a) and (50b), which are also the two rules responsible for reducing the four representations of /a/ in (60) to one matrix. It seems to us, therefore, that features can be considered equally basic in both CUT and RUT.

2.3. Single-valued feature systems for vowels

From one viewpoint, a single-valued feature approach represents an extreme form of underspecification. The claim is simply that the so-called default value can play no role in the phonology whatsoever. Thus, a single-valued system reflects the spirit of underspecification in expressing markedness considerations directly, but it does so in a more rigorous way. Furthermore, there is no a priori reason for assuming that the other motivations in favour of (radical) underspecification (the SCC, the Locality Condition) cannot also be used to motivate single-valued features.

An immediate consequence of using single-valued features is that we no longer need the FSP. Also, there is no need, of course, for default rules, which renders the ROC superfluous as well. The whole issue of ternary power also immediately disappears from the scene. Clearly, in a single-valued system it is never the case that both values are present. The conclusion seems to be that both the FSP and the ROC are artefacts of a theory which uses binary features and this only strengthens the point that we are making here.[32]

The claim that features are single-valued has a weak and a strong variant. In the weak form the claim is that *some* features are single-valued. For example, various scholars have suggested that [round] is single-valued (Steriade 1987b, Archangeli to appear). Recently, Mester & Itô (1988) have argued that [voice] is a single-valued feature. Goldsmith (1985; 1987) goes further and uses a system in which both [round] and [low] are single-valued, with the proviso that the scope of [low] is extended to low AND mid vowels. In his system, [back] is still binary. The strong form of the claim implies that ALL features are single-valued. This position has been defended most extensively by proponents of Dependency Phonology (Anderson & Ewen 1987) and various others.

The use of single-valued features not only leads to a reduction of the phonological machinery, but it also reduces the amount of phonological computation. Most importantly, however, it leads to a more constrained theory. To the extent that we derive correct predictions from taking this more restrictive position, we have an argument in favour of single-valued features. One argument, involving the behaviour of neutral vowels in harmony systems, is offered in Van der Hulst & Smith (1986). Here we do not want to focus on arguments in favour of strict unarity. Clearly, it would be more productive to consider the arguments which argue against using only single-valued features. Problems usually involve reference to "the other value", i.e. the unmarked value, which in a single-valued approach has absolutely no existence in the phonology. Special cases of this type involve reference to BOTH values. Such cases, of course, would also be problematic for RUT. We refer to Van der Hulst (this vol.) for a discussion of various cases which might, *prima facie* at least, pose a threat to the single-valued approach.

Ignoring these cases here, let us now have a closer look at some specific unary feature systems for vowels.[33] In particular, we will discuss and compare the feature system of Dependency Phonology (DP; Anderson & Ewen 1987), Kaye, Lowenstamm & Vergnaud's (1985) Charm Phonology (CP), Van der Hulst (1987; this vol.), and, to a lesser extent, Schane's (1984) Particle Phonology (PP). Given the scope of the present article, the discussion will be limited to the basic points of correspondence and disagreement between the various proposals.

Let us note at the outset that the feature systems that we focus on in this section all differ from the SPE system not only in that they use unary rather than binary features, but also in choosing different parameters for characterising the vowel space. Whereas the SPE system is bidirectional (just like, for instance, the unary feature system proposed by Sanders 1972) in that it uses only the high-low and the front-back dimensions in the description of vowels, lip-rounding being superimposed on these two dimensions, the feature systems of CP, DP and PP (with the – at least partly – binary-valued theories of Goldsmith 1985; 1987 and Rennison 1986) are tridirectional.

Characteristic of tridirectional feature systems is the fact that they at least employ three basic primes in their feature set, corresponding to the three extremes of the vowel triangle, high front/palatal, high back/round and low. These three basic primes are commonly represented by the letters I, U and A, respectively, as summarised in (61).

(61) *The basic primes of tridirectional unary feature systems for vowels*
[I] – "frontness/palatality"
[U] – "high backness/roundness"
[A] – "lowness"

From a phonetic point of view, these features, which on their own represent the vowels /i/, /u/ and /a/, are clearly basic. They constitute the so-called quantal vowels, that is, they are the acoustically most stable vowels, in that their acoustic effect can be produced with a fairly wide range of articulatory configurations. In addition these three vowels are maximally distinctive, both from an acoustic and an articulatory point of view. Moreover, /i/, /u/, and /a/ are also basic as far as phonology is concerned. They constitute the canonical three-vowel system, and they are also the first vowels that children acquire. Hence it turns out that the choice of [I], [U] and [A] as basic vocalic features is well-motivated, both phonetically and phonologically.

With the aid of these three vowel components, at most seven vowels can be characterised, if we bear in mind that they can be used not only in isolation, but also in combination with each other.

(62)	{I}	{U,I}	{U}
	{I,A}	{U,I,A}	{U,A}
		{A}	

It will be obvious that these seven representations do not exhaust the maximal number of different vowels that are found in the language systems of the world. The existence of vowel systems containing nine or even more elements forces one to look for some way in which the total number of vowels describable in terms of (combinations) of the three basic vocalic components [I], [U] and [A] can be increased.

There are in principle two ways in which this increase of the combinatorial potential of the three features can be achieved. Either one assumes that features can occur more than once in a particular representation, or one takes the view that one of the features in a feature combination can be prominent with respect to the other feature(s). Of these two conceivable positions, the former is defended by Schane (1984), while CP and DP both invoke the concept of dependency to arrive at a larger number of possible representations. Thus compare, for instance, the DP and PP representations of the vowel /E/ in the partial vowel system in (63).

(63)	/i/ ---------------	DP: {I}	/ PP: {I}
	/e/ -----------	DP: {I;A}	/ PP: {IA}
	/E/ ---------	DP: {A;I}	/ PP: {IAA}
	/a/ ------	DP: {A}	/ PP: {A}

When we compare the two feature frameworks that make use of dependency relations, it appears that there is a difference between CP on the one hand, and DP on the other, resulting from the fact that DP, unlike CP, also allows the features [I] and [U] to enter into a relationship of "mutual dependency" with [A], a relationship in which neither component counts as the head. Thus DP maximally generates the following set of representations on the basis of the features [I], [U] and [A] (which DP represents as |i|, |u| and |a|).

(64) *The maximal number of combinations of* [I], [U] *and* [A] *in DP*

{|i|}	{|u,i|}	{|u|}
{|i;a|}	{|u,i;a|}	{|u;a|}
{|i:a|}	{|u,i:a|}	{|u:a|}
{|a;i|}	{|a;u,i|}	{|a;u|}
	{|a|}	

Thus at most four front vowels and four (rounded) back vowels can be described, plus the low vowel and a set of front rounded vowels. Still, however, this is not enough to characterise all possible vowels and vowel systems of the world's languages. In particular the central vowels, and also the back unrounded vowels, cannot be represented on the basis of (64).

It should be emphasised, however, that the table in (64) does *not* exhaust the combinatorial potential of the three components of DP. As one will notice, although the features [I] and [U], and their combination [I,U], can enter into all the various dependency relations with the lowness component [A], what we do not find in (64) are asymmetrical combinations of the two features. Although the system of DP would in principle allow for the gradual oppositions {|i|} vs. {|i;u|} vs. {|i:u|} vs. {|u;i|} vs. {|u|}, it turns out, as Anderson & Ewen (1987:275) have observed, that "in virtually all languages, we find at each height maximally one segment containing both |i| and |u|; in other words, dependency relationships holding between |i| and |u| are not required". Yet, although they may not be required in practice, the fact remains, and we want to emphasise this here, that nothing in the theoretical framework of DP renders dependency relations between the features [I] and [U] impossible on a principled basis.[34]

The same applies, in fact even more so than to DP, to Schane's (1984) Particle Phonology, in which it is also unclear why {UI} is allowed, whereas {IIU}, {UUI}, {IIIU}, {UUUI} etc. are apparently superfluous. The problem is aggravated even further once one realises that, within Schane's system, there is no way in which one can put an upper bound upon the maximal number of occurrences of a given feature in a particular representation. Hence, in Schane's Particle Phonology, the door is widely opened for astronomical repetitions of the three components. Schane encounters this problem not only in relation to the combinatorial possibilities of [I] and [U], but of course also with respect to the combination of either or both of these features with the lowness feature [A]. In principle, Schane's system allows for an unlimited number of different vowel heights, therefore, as has often been noted in the literature (for a recent discussion, see Hyman to appear). It is for this reason that we will not pay any specific attention to Schane's Particle Phonology in what follows, and limit ourselves to CP and DP, which lack such gross overgeneration on this score. We stress, though, that Schane does provide many valuable arguments for the single-valued features [I], [U] and [A].

To return now to the problem that DP has in common with Particle Phonology, i.e. the fact that both theories in principle allow for more combinations of [I] and [U] than are strictly necessary, we point out a significant advantage on this score on the part of Kaye, Lowenstamm & Vergnaud's (1985) Charm Phonology. In CP a principled answer is available to the question as to why head-dependent relationships between [I] and [U] are absent. In order to be able to demonstrate this, we must first of all provide the reader with some details of the CP system.

In CP every feature, or element in Kaye *et al.*'s terminology, is an individually pronounceable unit associated with a fully specified feature matrix, consisting of traditional SPE-type binary features.[35] These binary features specify the content of the elements, but the elements themselves are the primitives used in phonological descriptions. The feature matrix of each element of CP – except for that of the so-called "cold vowel" which we will discuss later on – has precisely one "hot feature", which represents the most salient property of the element in question (it is the marked feature value in the matrix). This hot feature plays a crucial role in determining the output of the combination, or – in Kaye *et al.*'s terms – fusion of two elements. Fusion of two elements is defined in CP as substitution of the value of the hot feature of the operator (or dependent) for that of the corresponding feature of the head (or governor). All other feature values of the newly-formed composite element are those of the head.

Now let us see what all this entails for the fusion of the features [U] and [I] in the CP framework. Consider first of all the feature matrices belonging to [I] and [U], in which the "hot feature" is written in capitals.

(65) $$[\mathrm{I}] \quad \begin{bmatrix} \text{-round} \\ \text{-BACK} \\ \text{+high} \\ \text{-low} \\ \text{-atr} \end{bmatrix} \qquad [\mathrm{U}] \quad \begin{bmatrix} \text{+ROUND} \\ \text{+back} \\ \text{+high} \\ \text{-low} \\ \text{-atr} \end{bmatrix}$$

If we fuse [I] and [U] with the former as operator and the latter as head, we arrive at the feature matrix [+round, –back, +high, –low, –atr]. If, alternatively, we fuse these two elements with [I] as head and [U] as operator, we derive [+round, –back, +high, –low, –atr], which is precisely identical to the result of fusing [I] and [U] with the head-operator relation reversed. What we see, then, is that within Charm Phonology the apparent absence of dependency relations between [I] and [U] is accounted for on principled grounds. Clearly, this is a major advantage of CP in comparison with the systems of Particle Phonology and Dependency Phonology, in which the absence of more than one occurrence, or more than just simple combination of the features [I] and [U] is merely a matter of chance.

Let us return now to the issue that we started out discussing at the beginning of this section: the total number of vowels that can be described on the basis of the feature systems of CP and DP. Given that asymmetrical fusion of [I] and [U] is impossible, as we have shown above, the maximal combinatorial potential of the three basic vowel components is represented in the chart in (64) above, on the assumption that fusion may also involve mutual or bilateral dependency, as in DP. However, as we already noted earlier, this is not enough. Even though, with the aid of the set of representations in (64), the maximal number of possible vowel heights can be described, the system is at a loss as far as the characterisation of the central and back unrounded vowels is concerned. It is for the purpose of their description that DP has introduced a separate component, |ə|, "centrality" or "non-peripherality". With the introduction of this component, the total set of possible central vowels can be described in terms of |ə| alone or in combination with the lowness component, |a| (cf. the DP characterisation of the Kpokolo central vowels in (71)), while back unrounded vowels are represented with the aid of |ə|, |i| and |u| together, combined with |a| to show height alternations, as in (66).

(66) *The DP representation of back unrounded vowels:*
/ɯ/ – {|ə,u,i|}
/ɣ/ – {|ə,u,i;a|}
/ə/ – {|ə,u,i:a|}
/ɑ/ – {|a;ə,u,i|}

Although it is clear that, within a theoretical frame such as that of DP, this fourth component is indispensable, it seems that the introduction of |ə| is not a very elegant addition to the feature system: Schwa being clearly not maximally distinctive, one would not normally look upon |ə| as a phonetically basic component. Yet, as Anderson & Ewen (1987:279) indicate, "the data surveyed by Crothers (1978) and Lass (1984) appear to show that a component with a 'centrality' gloss is indeed phonologically basic, in much the same way as |i|, |u| and |a|".

Charm Phonology also makes use of a kind of centrality component, although they have a different name for it: the "cold vowel" [v], which we have already mentioned in passing above. This is "a vowel with no hot features" (Kaye *et al.* 1985:368), which, although superficially quite similar to DP's centrality component, differs from |ə| with respect to its function in the system, a difference which is caused precisely by the cold vowel's lack of a hot feature. Given the fusion calculus used in Charm Phonology as defined above, and in view of the fact that the cold vowel is characterised by the feature matrix in (67), it follows that every fusion of the cold vowel with [I], [U] or [ATR], which differ from [v] only in their hot feature, will always result in a compound element whose head has the feature make-up of [I], [U] or [ATR], respectively, since [v] itself lacks a hot feature. The only instance where fusion of an element with the cold vowel is not vacuous is in the case of the combination of [v] and [A], with the latter as operator, which results in a [–round, +back, –high, –low, –ATR] vowel (i.e., a "raised" /a/), as the reader will be able to check for himself, given that [A] is defined as [–round, +back, –HIGH, +low, –atr].

(67) THE COLD VOWEL [v]: $\begin{bmatrix} \text{–round} \\ \text{+back} \\ \text{+high} \\ \text{–low} \\ \text{–atr} \end{bmatrix}$

Thus the introduction of the cold vowel into the feature set of CP does

DP needs a separate ATR component at all. Anderson & Ewen (1987: 305) conclude, however, that for the description of ATR-harmony systems "it is clear that, in common with other single-valued approaches, we require an ADVANCED TONGUE ROOT component, which we will represent as $|\alpha|$". This may well be true, and we certainly would not like to question the validity of the ATR feature in general, but notice that within a system such as Dependency Phonology the presence of a separate ATR component alongside an elaborate set of dependency relations, including mutual dependency, would seem to mark a redundancy, since it is clear that such a theory can express oppositions of vowel height in a variety of ways.[37]

Faced with this point of criticism, the dependency phonologist could, in principle, do either of two things: he could either give up a separate ATR component so that he would have to find another way to describe ATR harmony phenomena (possibly in terms of $|a|$-spreading), or he may choose to abandon the concept of bilateral, or mutual dependency. Now notice that, whereas in an intuitive sense it is immediately clear what it means for a feature or component to be a governor or a dependent, the intuitive conception of the notion of mutual dependency is far less clear. Also, when we look at the dependency relations between the other components employed by DP, it turns out that a vast minority of components can enter into a relationship of mutual dependency. One area within DP outside the vowel components where we find bilateral dependency is between the two components of DP's phonatory subgesture (cf. section 1.2.1), $|V|$ and $|C|$. As we will show in the next section, however, it turns out that a reanalysis of DP's representation of the major classes in which $|V{:}C|$ is not required is not only possible, but also has some significant advantages over the standard-DP representations.

The conclusion that may be drawn from the preceding discussion is that, for an adequate characterisation of the major segment classes, DP need not invoke the notion of bilateral dependency. Since elsewhere in the DP framework the status of this dependency relation is both rare and questionable, one may well cast some doubt upon the relevance of mutual dependency in general. If, then, we decide to remove this concept from the theory of dependency phonology, we immediately rid ourselves of the objection that DP has essentially two ways in which distinctions among vowels of different heights can be made, viz. by way of the ATR component, or mutual dependency, and at the same time we bring DP and Charm Phonology closer together.

At this point let us note that in the DP system there is no possibility of formally expressing the relative markedness of particular feature combinations. That is, within this system there is no formal property associated to the components that renders it intrinsically unfavourable for two components to go together in the representation of a given segment. In principle all five vocalic components can freely combine with one another. Yet, as Kaye, Lowenstamm & Vergnaud (1985:371) point out, "even a cursory look at segmental structure ... shows that there do exist classes of elements sharing a particular property. This property has an impact on the combinations of elements that may exist and on their organisation into segmental systems (vowels or consonants)". In the feature system of CP this property is hence given formal status, and is called CHARM. It is assumed that there are positively and negatively charmed elements, and that combination of elements with like charm is strongly dispreferred, whereas there is an attraction between elements of unlike charm. CP's proliferation of positive and negative charm among its vowel elements is as in (72).[38]

(72) $[A]^{+}$
$[ATR]^{+}$
$[I]^{-}$
$[U]^{-}$
$[v]^{-}$

The property of charm, Kaye, Lowenstamm & Vergnaud (1985:371) argue, may intuitively be related to "voweliness" in the sense that positively charmed elements, which have a resonating cavity (for [A] the oral cavity, for [ATR] the pharyngeal cavity, and for [N] (cf. fn. 38) the nasal cavity), are the archetypal vowels. In general, the charm of a compound expression, i.e. a combination of two elements, is the charm of its head.

From (72) we may now derive the extent to which certain combinations of elements are preferred. We can divide these possible combinations into two classes, preferred and dispreferred ones, as in (73).

73)

Preferred combinations:	Dispreferred combinations:
[A] + [I]	[A] + [ATR]
[A] + [U]	[I] + [U]
[A] + [v]	[I] + [v]
[I] + [ATR]	[U] + [v]
[U] + [ATR]	
[v] + [ATR]	

It turns out, though, that of the set of dispreferred combinations the latter three are actually not infrequent. In fact two of them ([I] + [v] and [U] + [v]) are found in the vowel system of Kpokolo discussed above, while [I] + [U] occurs in vowel systems containing front rounded vowels such as /y/. Thus we may choose to reformulate the fusion calculus slightly (although Kaye *et al.* themselves do not explicitly do so) by assuming that fusion of two elements with like charm is allowed so long as the elements in question are both *negatively* charmed. Negative charm can then be seen as absence of charm (cf. single-valued feature phonology, in which [–F] is represented as the absence of F) while positive charm is the presence of charm. With this interpretation of the notion of charm, only two positively charmed elements will resist fusion. The other elements simply do not have charm at all, and can hence, in principle, be combined with any other element in the (revised) CP system.[39]

What the CP feature system, embodying the notion of charm, is able to express formally, then, is that fusion of [A] and [ATR] is not highly valued in a feature system. This is taken to account straightforwardly for the absence in most ATR vowel systems of a [+ATR] counterpart of the low vowel /a/. In vowel systems in which /a/ does have a [+ATR] counterpart, such as Kpokolo, where /ə/ is the [+ATR] variant of the low vowel, a special procedure must be followed. Kaye, Lowenstamm & Vergnaud (1985: 377) argue that "in situations where the positively charmed ATR element seeks to fuse with [A] there are apparently two possibilities: (1) the positive charm of [A+] prevents association; (2) the roles of operator and head are reversed and a negatively charmed expression is formed, to which the positive ATR element can associate". In languages in which /a/ has a [+ATR] counterpart, then, the second strategy will be adopted. In particular, the expression (v–.A+)+ is replaced by (A+.v–)–, which is subsequently combined with [ATR+] to form ((A+.v–)–.ATR+)+. We have illustrated this schematically in (74).[40]

(74)
```
 * ATR      ATR
    |        |
----v--------V-----
    |        |
----A--------a-----
```

The concept of head-operator reversal, introduced for the description of the [+ATR] variant of the low vowel, strikes us as rather ad hoc. Yet we admit that the intuitive idea behind the notion of charm is sound, albeit that the way in which Kaye, Lowenstamm & Vergnaud (1985) have chosen to capture it may not be the most felicitous.

Let us now return once more to the features [ATR] and [ə]/[v], which both CP and DP seem to require. It should be noted that these two components or elements differ from the other three features [I], [U] and [A], in particular because they are clearly not as basic as the other three components or elements. The different status of [ATR] and [ə] (or the cold vowel) as compared with [I], [U] and [A] is given formal recognition in the system of CP. There, as we saw above, [ATR] and the cold vowel are assumed not to occupy tiers of their own, in contradistinction to the other elements of CP. [ATR] and the cold vowel, in addition, differ from each other as well, in that the latter, even though it does not have its own tier, does always occur on some other autosegmental line, where it fills up the gaps, whereas [ATR] never finds itself on any line at all, and as a consequence can never be the head of a complex expression, as opposed to the cold vowel. In addition, the ATR element functions peculiarly with respect to charm (cf. fn. 40). Yet, although the [ATR] element clearly has a number of ad hoc properties, the cold vowel is not an unnatural ingredient of the CP system. The cold vowel has no hot feature and as such it fills the obvious gap in the CP feature system, being the one really unmarked element. The only really peculiar property of [v] is that it does not have its own line: In fact, [v] can occur on *any* line. In the feature system of DP, on the other hand, both [ATR] and – in particular – the centrality component are inelegant "intruders" particularly because it is not at all obvious why they should be present and why it should precisely be these two components. Moreover, as pointed out above, the introduction of especially |ə| leads to tremendous overgeneration in DP (unlike CP).

It is precisely these two features, [ATR] and the centrality feature/cold vowel, that are eliminated from the set of single-valued vowel features by Van der Hulst (1987; this vol.). He proposes that there are three basic vowel features, [I], [U] and [A], whose phonetic interpretation depends on their status as a head/governor or an operator/dependent, as summed up in (75).

(75)	Interpretation of [U]	– Head:	Velar constriction
		Operator:	Rounding
	Interpretation of [I]	– Head:	Palatal constriction
		Operator:	Advanced Tongue Root
	Interpretation of [A]	– Head:	Pharyngeal constriction
		Operator:	Openness

From (75) it is immediately clear that the need for a separate ATR feature is obviated by Van der Hulst's feature interpretation: ATR is operator-[I]. How Van der Hulst is able to dispense with [ə] is something that depends crucially on the dual interpretation given to [U], to which we turn now.

The dual character of [U] is strongly motivated. This feature has always had a dual function in tridirectional feature systems: it stands for velarity and roundness at the same time. A number of phonologists, notably Lass (1984) and Rennison (1986), have argued that these two aspects of [U] should in fact be given independent status, thus splitting up |u| into two features, |ω| ("labiality" or "roundness") and |ɯ| ("velarity" or "high backness"). DP argues that such a move, in spite of making a representation of back unrounded vowels possible without the use of a centrality component, is undesirable since it forces one to give up the direct relationship between markedness and formal complexity reflected by the standard DP system. That this is so follows straightforwardly from a comparison of the standard-DP representations of a high back rounded vowel and a high back unrounded vowel with those of Lass (1984), given in (76).

(76)	The representation of /u/:	The representation of /ɯ/:
	standard-DP: {|u|}	standard-DP: {|u,i,ə|}
	Lass (1984): {|ɯ,ω|}	Lass (1984): {|ɯ|}

Thus, whereas in the standard-DP system /ɯ/ is formally more complex than /u/, this situation is reversed in Lass's (1984) feature system. Since it is clear that a high back vowel that is rounded is less marked than an unrounded one, Lass's (1984) system clearly does not mirror markedness (as Lass himself also explicitly acknowledges). In addition, his proposal enlarges the number of phonological primes, since it seems unlikely that, by splitting up the |u| component into |ω| and |ɯ|, the centrality component can be dispensed with altogether. Hence it seems best not to give the two aspects of |u| independent status as components or features.

Van der Hulst (1987; this vol.) provides a way in which we can distinguish formally between the two constituent parts of [U] without this feature having to be split up, by interpreting it as in (75). Thus we see that the dual status that has always been inherent in the [U] feature of tridirectional single-valued feature systems can be captured in a principled way once one exploits the concept of dependency more thoroughly.

The dual interpretation of [U], given in (75), is thus like Lass's (1984) proposal, except that in the former approach the number of phonological primes is not increased. Both proposals are preferable to the standard-DP system, in which no formal recognition is given to the duality of [U], from the point of view of labial or rounding assimilation, a phenomenon that we discussed in section 1.2.2 in relation to the hierarchy of phonological features. As noted, for instance, by Sagey (1986), in a language such as Tulu, rounding assimilation can be triggered not only by lip-rounded vowels, but also by labial consonants, whose articulation need not involve lip-rounding at all. For Sagey this process provides evidence for her labial class node, as we noted above. In standard-DP, this assimilation process can in principle be captured simply in terms of the autosegmental spreading of a roundness component, which is found in the DP representations of both rounded vowels and labial consonants, the latter being characterised as in (77).

(77) DP representation of labial consonants: {|u|}

It should be noted, however, that in standard-DP the |u| component is also used in the representation of velar and uvular (so high back) consonants:

(78) a. velars: {|l,u|} b. uvulars: {|l,u,a|}

Thus standard-DP would wrongly predict velars and uvulars to also trigger |u| harmony.

It will be clear that in the feature systems of Lass (1984) and Van der Hulst (1987; this vol.) this incorrect prediction is not made. In Lass's (1984) system, labial harmony is characterised by the autosegmental spreading of |ω|, a component which velars and uvulars clearly lack, and under Van der Hulst's assumptions, rounding harmony involves the spreading of an operator |u|, which represents lip-rounding, or labiality. Again, velars and uvulars do not have this operator |u|, while labials and rounded vowels do. This, then, is clearly a point in favour of the position that the dual status of DP's |u| component should be given formal recognition in the theory.

In Van der Hulst (1987; this vol.) it is suggested that the dual interpretation of [U] enables us to rid the feature system of the centrality feature. Recall that Dependency Phonology makes crucial use of |ə| in its description of back unrounded vowels. By interpreting the vowel features as in (75), a characterisation of these vowels is available in which there is no need for |ə|, as appears from (79).

(79)	/ɯ/	/u/
	U	U
		|
		u

An objection that can be made against these representations is that they, just like those of Lass (1984), wrongly predict a high back unrounded vowel to be less marked than its rounded counterpart. This appears from the representations of the two vowels in (75). Van der Hulst (1987) points out, however, that "one should not fail to notice that it is the presence of /ɯ / in a system which causes this complexity. It is not clear that 'system-complexity' should be reflected in the representation of the sounds whose presence presupposes the presence of certain other sounds."

In this section we have discussed a variety of single-valued feature systems for vowels. As we observed at the beginning of this section, a unary feature system is theoretically more restricted than, and hence preferable to a binary feature theory such as SPE. Nonetheless, as we have seen, the single-valued vocalic feature systems that are currently most authoritative, Charm Phonology and Dependency Phonology, both contain a number of undesirable aspects. In particular, we point to the fact that both feature systems have to add to the three basic vocalic features, [I], [A] and [U], two elements or components whose theoretical status (especially in DP) is far less well-established than that of [I], [U] and [A]. This shortcoming of CP and DP can be overcome once we reinterpret these three basic vowel features along the lines suggested in Van der Hulst (1987; this vol.).

3. MAJOR CLASS FEATURES AND SONORITY

In this section we will discuss an area of feature theory which has been mentioned in passing in the foregoing discussion, viz. the major class features. Above, features like [consonantal] or [sonorant] have been mentioned in relation to the question as to where they should be located in a geometrical approach. Here we want go into the *choice* of major class features. Of central interest is the question of how major class features are represented such that their role vis-à-vis syllable formation can be made explicit. In this connection the question arises as to how major class features relate to the concept of sonority. We will first discuss these issues within the context of a binary feature system, basing ourselves upon recent work by Clements (e.g. 1987a). Then we discuss a rather different approach using single-valued features, taking the system of DP as our point of departure. Finally, we discuss the skeleton.

3.1. Binary categorial features and the sonority hierarchy[41]

Two features play an essential role in differentiating between so-called major categories of sounds: [consonantal] and [sonorant]. The definitions of these features point to relative rather than absolute properties:[42]

(80) [consonantal]: Sounds which are [+consonantal] are produced with a relatively high degree of constriction

(81) [sonorant]: Sounds which are [+sonorant] are produced such that the airstream passes unimpeded through either the nasal or oral cavity

Liquids and nasals will be [+consonantal] because there is a high degree of (in fact, a total) constriction, but the constriction is such that the airstream passes via a different route, unimpeded, which is why they are also [+sonorant]. Given these definitions, [–consonantal] implies [+sonorant]. This leaves us with three classes of sounds:[43]

(82)

	obstruent	sonorant consonant	vowel
[cons]	+	+	–
[son]	–	+	+

Usually, within the class of sonorant consonants, nasals and liquids are also set apart as major categories, which raises the question as to whether we should invoke another major class feature, or simply use a feature like [nasal]. Using [nasal] would also predict sonority differences between nasal and non-nasal liquids and vowels. A decision regarding this issue depends on one's point of view on the representation of "sonority". Most researchers will agree that major classes of segments can be ranked according to their suitability to occur in the nucleus of syllables. This ranking will at least mention the following categories:

(83) obstruent nasal liquid vowel

Vowels, then, are more likely to constitute or be the head of the syllable nucleus than liquids, which in turn are better suited for this purpose than nasals, the least likely candidate being an obstruent.

An important question is how we can derive the multivalued scale in (83) from the featural representation of segment classes. Probably the least interesting answer consists in invoking a multivalued feature [sonority] (cf. Selkirk 1984, Van der Hulst 1984). Such a feature would be odd in both a binary and a single-valued framework to begin with, and it is questionable whether its formal uniqueness (being multivalued) is sufficient to explain why [sonority] rather than properties like [anterior], [lateral] or [ATR] determine the syllabic behaviour of segments.

Clements (1987a) argues that the amount of sonority arises from a cumulative effect to which the major class features all contribute. Hence, the property of being [–consonantal] implies some amount of sonority, while being [+sonorant] implies some more. This would not give a sonority difference between nasals and liquids, however, because both liquids and nasals are [+cons, +son]. To solve this, Clements introduces another feature, [approximant], which can be defined in articulatory terms (after Ladefoged 1982:70) as follows:

(84) [approximant]: A segment is [+approximant] if there is a non-turbulent ORAL airstream

Liquids and vowels involve a constriction which does not cause friction or a turbulent airstream; hence they are [+appr]. Notice that this feature almost duplicates [sonorant]. It only differs in being restricted to a friction caused by the ORAL airflow, causing nasals and liquids to fall into different classes.

Assuming that being [+ appr] adds to sonority, it is explained why liquids are more sonorant than nasals. Given the definitions of [consonantal], [sonorant] and [approximant] the following redundancies hold universally:

(85) a. [–cons] → [+appr] $\dashv\vdash$ [–appr] → [+cons]
(if there is a low degree of constriction, this implies a low degree of ORAL constriction)
b. [+appr] → [+son] $\dashv\vdash$ [–son] → [–appr]
(being [+appr] means being [+son]: if the oral constriction does not cause friction, the airflow is not impeded)

Only four out of the eight logically possible combinations are well-formed, then, and these are given in (86), from which the redundant specifications have been eliminated.

(86)

	O	N	L	V
[cons]			+	–
[appr]		–	+	
[son]	–	+		

This in itself does not tell us anything about sonority yet. However, as pointed out in Farmer (1979), when we substitute the +/– specifications by markedness specifications, we arrive at a different picture. Kean (1975) develops a marking convention for the major class feature set consisting of [syllabic], [consonantal] and [sonorant], according to which [–consonantal] is marked (as in SPE), whereas [+sonorant] is also marked. This suggests, as in fact has been suggested in Farmer (1979), that sonority is directly related to markedness. If this holds then [+appr] must be considered marked, because, as we know, [+appr] sounds are more sonorous than [–appr] sounds:

(87)

	O	N	L	V
[cons]	u	u	u	m
[appr]	u	u	m	m
[son]	u	m	m	m

Given this table, relative sonority is proportional to relative markedness or complexity (only "m" adds to complexity) and this is essentially what Clements (1987a) suggests:

(88)

O	N	L	V	
0	1	2	3	relative sonority

A "translation" to underspecification theory entails inserting the unmarked values by default rules, which, in combination with the redundancy rules, leads to the following:[44]

[−cons] = lexical

(89) a. i. [ ] → [+cons]

ii. [−cons] → [+appr]
iii. [ ] → [−appr]

iv. [+appr] → [+son]
v. [ ] → [−son]

b.

	O	N	L	V	
[cons]				−	
[appr]			+	+	
[son]		+	+	+	
	0	1	2	3	relative sonority

However, counting lexical, i.e. marked specificiations to arrive at relative sonority does not work, of course, if we take into account the fact that certain specifications in this table are redundant and have to be left out:

(90)

	O	N	L	V
[cons]				−
[appr]			+	
[son]		+		

However, even if we adopt this position, we can still derive sonority from the featural system. Note that the three features used in (90) stand in a hierarchical ordering relation in the sense that introducing the redundant value for [son] depends on the prior assignment of the redundant values for [appr], which, in turn, depends upon the fact that the value "–" for [cons] is lexical. Hence, the features at issue here are hierarchically ordered in such a way that [cons] is of the highest order, followed by [appr] and [son] in that order:

(91) [consonantal] > [approximant] > [sonorant]

This, then, gives us a straightforward way of deriving sonority: a higher-order specification translates into a higher degree of sonority.[45,46]

3.2. Unary categorial features and the sonority hierarchy

Given the definitions of [son], [~~voc~~ cons] and [appr], we easily get the impression that a continuum is arbitrarily broken down into formally unrelated binary features. A different approach seems to be that of DP, where, as is claimed, two orthogonal features [consonantal] (or |C|) and [vocalic] (or |V|), with traditional Jakobsonian definitions, are used to represent a whole array of major classes in such a way that their relative sonority is proportional to the preponderance of the feature [vocalic].

In DP, features are single-valued, and, as we have seen in previous sections, these features can stand in a relation of government, or dependency. So, |C| can govern |V|, or vice versa. This would give us four possibilities, which, at first sight, could be used to distinguish the four major categories O, N, L and V:

(92)
$$\begin{array}{cccc} C & C & V & V \\ & | & | & \\ & V & C & \end{array}$$

But this is not what is done in DP. Instead it is assumed that the categories of stops and fricatives should also be represented in terms of distinct categorial features. Recall that DP allows mutual dependency. This offers the possibility of adding a fifth category |C:V|. In the DP proposal, this combination of C and V itself can enter into dependency relations with V, so that we end up with the array of possibilities which we gave in section 1.2.1, and repeat here for convenience:

```
(93)  vclst      vclfri      vcdfr      nas     liq     vow
                 vcdst

                  C:V
                               C:V       V       V
         C                      |        |       |       V
                   C            V        C      C:V
                   |
                   V
```

As Anderson & Ewen (1987) do not fail to observe themselves, |C:V| represents [continuant] and it seems to us, therefore, that DP has three and not just two categorial features, and, we add, redundancy statements ruling out combinations of [consonantal] (|C|) and [continuant] (|C:V|), for which there seems to be no use:

```
(94)   * C:V          *  C
          |              |
          C             C:V
```

It is almost the case, then, that in DP, too, sonority is scattered across three independent features. To end this subsection constructively, let us therefore consider an alternative to the DP approach, involving an extension of the approach to single-valued vowel features made in Van der Hulst (1987; this vol.) to the categorial features. Recall from the discussion in section 2.3 that the basic idea there was that the interpretation of a unary feature is dependent on its status as either a head or a dependent. So |u| in governing position basically represents backness, whereas |u| in dependent position only seems to represent rounding. As briefly mentioned in section 2.3, it is shown in Van der Hulst (1987; this vol.) that a generalisation of this to the three vocalic features |i|, |u| and |a| leads to a reduction of the number of phonological primitives, and, more importantly, to encouraging analytical results. One aspect of the proposal involves allowing a feature to govern itself. This implies that two features allow eight distinct representations, which, we claim, can be naturally linked to the eight classes which DP proponents wish to distinguish:

```
(95)  C     C      C     C     V     V      V     V
      |    / \           |     |    / \           |
      C   C   V          V     C   C   V          V

      vcl <vcd   =  vcl < vcd  <nas <liq  =  glide <vow
      stop stop     fric  fric
```

As in the case of the vocalic features, there is a striking correspondence between the various structural positions of the two features used here and features which have been proposed in binary systems:[47]

(96) a. The interpretation of |C|

Head : [–sonorant]
Operator : [–continuant] if governed by |C|
[+consonantal] if governed by |V|

b. The interpretation of |V|

Head : [+sonorant]
Operator : [+voice] if governed by |C|
[+vocalic] if governed by |V|

We refer to Van der Hulst (ms.) for further discussion of this proposal. Observe that in this proposal the use of dependency relations really leads to a reductionist view on categorial features.

3.3. The skeleton

As discussed briefly in section 1.1, in much current work a distinction is made between root nodes and skeletal nodes, or timing slots. There has been a debate concerning the question as to whether or not skeletal nodes are "labelled". Clements & Keyser (1983) employ a CV-labelling and they argue that having this labelling renders redundant assigning internal constituent structure to the syllable. Others, however, have argued that by making modest reference to a syllabic hierarchical structure, terminals could be left unspecified (e.g. Levin 1985, Lowenstamm & Kaye 1986):

(97) a. C V C b. $\begin{array}{ccc} & \text{Nuc} & \\ & | & \\ \text{X} & \text{X} & \text{X} \end{array}$

However, it seems to us that, as long as the C/V symbols encode syllabic organisation, there really is no issue here at all. The point is made clearly in Hayes (1988: 232): "There is redundancy no matter which direction you go, so the redundancy itself cannot dictate the correct solution."

A related issue is whether the information encoded by "C" and "V" or the information encoded by "X" and "$\begin{array}{c}\text{Nuc} \\ | \\ \text{X}\end{array}$" itself forms part of the segmental representation. This seems to be a perfectly reasonable position. Such a move reduces syllable formation to associating the nodes labelled "C" and "V" to a syllable node, or adjoining bare X's to X's dominated by "Nuc". The latter position is explicitly adopted in Levin (1985) and Archangeli & Pulleyblank (in prep.). In that case, major class information takes the form of partially specified syllabic structure. This is not to say, however, that syllabic structure is regarded to be part of the underlying representation. Such a view would be undesirable, since, as Hayes (1988:232) points out, "there is a good reason to exclude syllable structure from underlying representation: languages appear never to allow different syllabifications of consonant clusters to contrast underlyingly, as in /a.bla/ vs. /ab.la/. This observation follows if it is the vowel-consonant distinction that is underlying and syllable structure that is derived."

Let us now discuss the DP view on these matters. In DP, syllabic structure is also regarded as being exhaustively determined by the segmental categorial information. Ewen (1986:269):

> "...the representations of the categorial gesture (specifically the phonatory subgesture) correspond to the elements of the CV-tier in the sense that they too define the distinction between syllabic peak and syllabic non-peak (in terms of relative prominence of |V|). Moreover, they are available for interpretation as units of timing in exactly the same way and thus convey the same information about segment status. Due to the independently motivated decision to assign greater structure to the feature matrix (or its dependency equivalent), there is no need to introduce a purely structural tier."

Ewen seems to imply that once you have a categorial gesture, it is no longer necessary to specify skeletal positions. But how are we to understand the idea that specifications of the phonatory subgesture are interpretable as timing units? Consider again the DP model of the segment:

```
(98)              o
           CAT          ART
          /   \        /   \
      Phon    Init   Vel    loc
```

In DP, complex segments such as affricates contain two phonatory subgestures, whereas a long segment has a double phonatory subgesture:

```
(99)   a.  |C|      |C:V|              b.  |V|      |V|
             \      /                        \      /
              [ART]                           [ART]

           (affricate)                     (long vowel)
```

It is not clear to us how the specification of the phonatory subsgesture can tell us anything about the "length" of the segment types in question. In other words, length cannot be represented subsegmentally, but has to involve direct reference to syllabic positions:

```
(100)  syllabic terminal        o   o
                                 \ /
       root                       o
```

In addition, we think that (99b) fails for another reason as well. Specifying a long segment with two categorial gestures entails a redundancy in that the categorial content of a long segment is specified twice.

Now, we do not of course have to label these syllabic nodes, nor do we need to include higher syllabic nodes, if we maintain that the category type of the syllabic constituent to which a segment associates is determined by the segment that is the head of this constituent. Whether the syllabic terminals are the old skeletal positions, or morae, as claimed by Hyman (1985), McCarthy & Prince (1986) and Hayes (1988), or the more traditional constituents onset, nucleus and coda, as in Steriade (to appear), is an independent issue. We will not address it here.

4. EPILOGUE

In this article we have discussed three topics in feature theory which seem to be central in the current literature. In each case we have reviewed a number of approaches and, in particular, we have contrasted analyses making use of binary features and approaches using a single-valued feature system.

Our major objective in this article has been to offer a comprehensive, yet inevitably selective state-of-the-art report, presenting as faithful a reflection as possible of the current positions and perspectives in the field of mainly segmental phonology. Thus we hope that, by our extensive criticism of the various proposals found in the current literature, we have paved the way for renewed research in the areas addressed here, leading to solutions for the problems that we have pointed out, and to further development of some of the – generally rather speculative – proposals made in this article.

NOTES

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1. The tree in (9) is the – at present – final stage of a discussion within the DP framework about featural hierarchitecture, beginning with Lass & Anderson (1975), whose phonatory gesture was later on renamed categorial gesture, and whose bipartite division was extended with a third main gesture, the initiatory gesture, introduced in Anderson & Ewen (1980) and Ewen (1980):

(i)

initiatory gesture categorial gesture articulatory gesture

This tripartite split was not felt to suffice either – essentially because it was considered to be "somewhat understructured" (Ewen 1986:205). As a result, DP introduced subgestures within gestures, and eventually developed the tree in (9) of the main text.

2. More discussion of the concept of dependency will be given in section 2.3, in relation to DP's representation of vowels. In the notational system of DP, a component enclosed between vertical lines represents just the component in question, while the representation {|x|} is used to exhaustively characterise a particular subgesture of a segment. DP also employs the notation {x}, which is used to express that the segment class in question is characterised by the component |x|, but not exhaustively so. A DP representation such as x;y denotes that |x| governs |y|, or that |y| is dependent on |x|. This representation is equivalent to the alternative representation with double arrows or the vertical notation used e.g. in (12), below, so that x;y equals x ⇒ y as well as

$$\begin{array}{c} x. \\ | \\ y \end{array}$$

3. Notice that the representations in (15) involve – at least if |n| occupies a subgesture of its own (cf. below) – intergestural dependency, a concept that, according to Davenport & Staun (1986), should be eliminated from the DP-model (cf. the discussion above, on the status and position of |O|).

4. The capital Ps and Ss in (16) refer to P(rimary)-place features and S(econdary)-place features, the former being used for the representation of consonants, and the latter primarily for the description of vowels. We will return to this distinction at the end of 1.2.2.2.

5. In 1.2.2.2 we will encounter another empirical counterargument against assigning [lateral] to the coronal node, coming from English coronal assimilation (cf. fn. 13).

6. It should be noted, however, that Sagey (1986: 47, fn. 17) has pointed out that it may well be possible and even desirable to treat the processes in Klamath as involving spreading of the root node, contrary to what was concluded in the previous paragraph. She does not dwell on this in any detail, but it seems clear that once we analyse the processes in (18) in terms of spreading of the root node we lose an argument against attaching the soft palate node, or, for that matter, the feature [lateral], above the supralaryngeal node. Of course, an analysis of the Klamath assimilation processes in terms of root note spreading also renders it quite mysterious why these assimilations display stability effects of the glottal state features associated with /L/ and /l'/, unless it is assumed that laryngeal features associate directly to the skeletal node. This may not be too strange a move in view of the fact that other laryngeal features (viz. the tonal features) have also been argued to associate directly

to the skeletal node (cf. Archangeli & Pulleyblank in prep.). In such a state of affairs the "root node" comes to dominate only supralaryngeal features, and can hence be renamed accordingly. The "skeletal node" may then just as well be called the root node, so that we may thus obviate the need for a separate skeletal tier mediating between segmental and suprasegmental structure (cf. McCarthy & Prince 1986; Hyman 1985).

7. Dogil (this vol.), who essentially follows Sagey (1986) in setting up his feature tree, is rather more articulate with respect to the manner features. Unlike Sagey, Dogil does include the features [lateral] and [strident] in his hierarchy, and joins them, together with [continuant] (which Sagey attaches to the root node), under a separate class node, the "stricture node". This stricture node in turn links up with the supralaryngeal node, together with the soft-palate and place nodes. Dogil continues to attach [consonantal] to the root node, while he deals with the feature [sonorant] in a structural way (cf. Dogil this vol. for details). In general, it should be stressed that Dogil's motivation for adopting his particular featural hierarchy does not come from phonological assimilation processes, but is based instead on acoustic facts. It seems unlikely that the features gathered under Dogil's stricture node will ever spread together in a phonological process, to the exclusion of all other features. Notice finally that Halle (1988) agrees with Dogil in adopting a stricture node, but differs from him in associating it directly to the root node rather than to the supralaryngeal node.

8. A note is due here with respect to the feature [strident]. Steriade (1986:4) points out that this feature is relevant only for continuant sounds. (Cf. Lass 1984, who uses this feature for labial and dorsal consonants.) In addition, Yip (1988) has observed that this manner feature applies only to coronal sounds. In view of these two observations it must be concluded that the presence of a specification for [strident] implies the presence of the feature [+continuant], plus a specification on the coronal node (Sagey 1986; this vol.). One might be tempted to express this apparently universal dependency of [strident] on [+continuant] and [coronal] formally in the featural hierarchy, but it is questionable whether this can be done in both cases. The only possibility that comes to mind is to attach [strident] under the coronal node, as is proposed by Yip (1988:79). In any event, it would seem to be impossible to also express the dependency of [strident] on [+continuant] formally in the feature hierarchy, which suggests that the incompatibility of some features has to be expressed in non-geometrical terms, e.g. in terms of feature cooccurrence restrictions.

9. Notice that Sagey's (this vol.) decision to attach [nasal] and [lateral] to the root node indicates that she now apparently believes that the assimilation processes in Klamath illustrated in (18) involve spreading of the root node rather than the supralaryngeal node, as in Clements (1985), an analysis that was anticipated in her dissertation (cf. fn. 6).

10. Yip (1988: 70), who adopts a feature tree that is essentially identical to Sagey's (1986), chooses to follow Clements (1985) rather than Sagey in adopting a manner node, joined under the supralaryngeal node. She does not adduce any arguments in favour of this choice, however. Notice, in a more general vein, that the supralaryngeal node exists iff it is distinct from the place node.

11. Notice that the Sanskrit assimilations in (20) might be taken to lend some support to Yip's (1988:79) suggestion that [strident] should be joined under the coronal node (so should be part of the place node). The assimilations in (20) turn a [+strident] sound, /s/, into a [-strident] sound, [Φ] or [x]. This loss of stridency would follow if [strident] is part of the node that is spread, given that the triggers of the assimilations are [-continuant] and hence [-strident] (cf. Steriade 1987a).

12. Since in this case both trigger and target are coronal it becomes possible to analyse this process as an OCP effect, as is suggested in Yip (1988); cf. Mester (1986; this vol.) and section 1.2.2.4 on the role of the OCP in the explanation of assimilations and cooccurrence restrictions of segments.

13. The case of English coronal assimilation is relevant furthermore for the determination

of the position in the feature hierarchy of [lateral]. As Clements (1985:236) points out, "[l] participates in this assimilation only in part, assimilating to [θ] (*health*) but not, at least not fully, to [č,ǰ] (*filch, bilge*)". For our purposes we need not concern ourselves with the defective participation of [l] in this process. What is relevant here is that this lateral does at least sometimes undergo coronal assimilation, and, more importantly, that, after this assimilation process has taken place, [l] retains its lateral articulation. This indicates that the feature [lateral] is not delinked as a result of coronal assimilation. Given that the process illustrated in (21) involves the spreading of this node from the coronal backwards to the preceding consonant, an analysis according to which [lateral] is placed under the coronal node would make the wrong predictions: in that case delinking the coronal specifications of the lateral in a word like *health* would entail delinking [lateral] as well. Since, however, the consonant preceding [θ] in *health* remains a lateral throughout, we must conclude that it is incorrect to attach [lateral] to the coronal node, as in Halle (1986) and Steriade (1986). Thus we have found some additional support for Sagey's (this vol.) position with respect to the position of the feature [lateral]. Notice, however, that the argument presented here does not imply that [lateral] must be attached as high as the root node, as in Sagey (this vol.): we are still free to join this feature under the place node. This tack is taken, *mutatis mutandis*, in Dependency Phonology (cf. 1.2.1), where the laterality component |λ| is a daughter of the locational subgesture.

14. Notice in relation to the tongue root node that the feature contained in it, [ATR], is not used solely in the description of vowels: as Trigo (1988) has argued, there are languages in which [ATR] is phonologically salient for voiced obstruents (as in Buchan (Aberdeenshire) and Madurese). The essential point of Trigo's paper is that the fact that the production of true voicing in obstruents requires an active enlargement of the supraglottal cavity achieved in part by tongue root advancement (cf. Westbury 1983, Kohler 1984) has a phonological (and not merely phonetic) reflex or function in some languages. Thus, in Buchan we find that a suffixal vowel that is underlyingly unspecified for [ATR] and height becomes [+ATR] and [+high] even if it follows a stem like *bed*, which contains a [-ATR, -high] vowel. Trigo analyses this phenomenon in terms of ATR harmony (the [+high] specification of the suffix vowel being added by redundancy rule). The trigger of this harmony process in the case at hand cannot be the stem vowel, which is [-ATR]. Rather, it must be the stem-final voiced obstruent /d/, which, by virtue of its being voiced, is [+ATR]. What this assimilation process shows, then, is that [+ATR] can be phonologically present in the representation of consonants, and be active in spreading processes. This would be unexpected if [ATR] (or the tongue root node) were contained in a node comprising vocalic place features only. (Notice, though, that the same holds of the labial node in (23); cf. the next subsection.) From a different perspective Trigo's paper also brings to light a tight relationship between voicing (glottal state) and ATR-ness. Once again, however, it is difficult to see how this relationship (or dependency) should be reflected in the feature tree.

15. Notice that the place node is special in that its daughters are mutually exclusive, just like the *values* of features. Thus it seems that nodes like [coronal], [labial], [dorsal] are *values* of the feature [place], just like + and - are values of, for instance, the feature [nasal]. Sagey (1986; this vol.) argues that having two place values leads to a *complex segment*, in which the different place values are linearly unordered, while having both a + and - value for some "ordinary" feature leads to a *contour segment*, in which the two values *are* linearly ordered.

16. For ease of exposition we will ignore the feature [ATR] and Sagey's (this vol.) radical/tongue root node throughout this subsection. Nothing crucial in the present discussion hinges on this omission.

17. In Archangeli (1987), a feature tree of this type is adopted. Her motives for opting for this tree have nothing to do with the C/V metathesis phenomena discussed by McCarthy

(1987), though. She points out that she is forced to postulate a feature geometry of the type in (25) in order for the contrast between minimal and maximal rules made in Archangeli & Pulleyblank (in prep.) to work out correctly. We will not go into this matter here.

18. This second process is restricted to non-low root vowels; /a/ can be combined with either a front or a back high vowel, the choice being lexically determined.

19. Notice that in the representations in (32) *both* values for the features [back] and [high] are specified in the underlying representations. This runs counter to the central claim of Radical Underspecification Theory (Archangeli 1984; Archangeli & Pulleyblank in prep.). For further details, we refer to section 2.2.

20. As mentioned in passing above, Mester (1986) makes a distinction between *universal* and *parametric* tier ordering. The former is instantiated by the Alur assimilations in (27) and the Ponapean ones in (29), the latter by the pair Ainu/Ngbaka. In the case of parametric tier ordering the features involved may not have an intrinsic hierarchical relationship, for otherwise we would expect only one head-dependent relation among these features to be possible, and not its reverse. Universal tier ordering, on the other hand, supposes a universal, intrinsic hierarchical relation between the features in question. It is *universal* tier ordering, then, that should directly be reflected by a feature tree à la Sagey (1986; this vol.) or others. *Parametric* tier ordering is only possible between features that are of equal hierarchical order in the feature tree.

21. Notice also that in the Kirghiz example in (36) [round] is dependent on [high], albeit indirectly. A similar case of dependent tier ordering in which [round] depends on [high], something that is impossible given Sagey's (1986; this vol.) feature tree, is found in Yawelmani Yokuts (cf. Archangeli 1984; 1985). Sagey (1986), who is aware of the parasitic harmony phenomena in Yawelmani Yokuts, does not look upon them as compelling evidence against the adoption of a separate labial tier. Rather, she refers to a recent reinterpretation of Yawelmani parasitic harmony by Cole & Trigo (this vol.), in which a dependency between [round] and [high] is no longer necessary. Yet, even though Yawelmani vowel harmony may well be describable in ways in which no dependency between various place of articulation features need be assumed, it is a moot point whether all harmony processes in which the autosegmental spreading of one place feature parasitises on the spreading of some other place feature can be reinterpreted along the lines suggested by Cole & Trigo (this vol.). Put differently, it is questionable whether dependency relations between individual members of different articulator nodes joined under Sagey's place node, which are impossible under Sagey's own assumptions, can or should be fully dispensed with.

22. Nasals are assumed to be unspecified for voicing, underlyingly, since in Javanese there is no contrast in voicing among nasals, all nasals being [+voice].

23. Mester (1986:105-109) argues furthermore for a dependency relation of [continuant] on [high] for palatal consonants in Javanese. Such a dependency would hold of palatals only. Since the position of the feature [cont] in the feature tree is far from clear anyhow, we will not discuss the consequences of this claim in what follows, however.

24. Hayes (1986) contains one other observation that might, at face value, be taken to run counter to the feature geometries found in the current literature. According to him, some of the assimilation processes in Toba Batak argue for a class node comprising the laryngeal features plus the feature [nasal], a node that is not distinguished in standard proposals on feature geometry. He labels this node the "Peripheral" tier (which is of an altogether different nature than the node of the same name proposed by Halle 1986). Hayes's argument is based primarily on a process whereby a nasal followed by a voiceless plosive is itself turned into a voiceless oral plosive, retaining all the place specifications of the underlying nasal. In this process both voicing and nasality are affected, but it cannot be the case – given that the place features of the target segment are unaltered – that spreading of the entire root node is involved. Hence, Hayes argues that a node must be spread that comprises

both the glottal state features (including [voice]) and [nasal]. Yet close scrutiny of Toba Batak shows that the need for a node comprising the glottal state features and [nasal] can easily be obviated once conscious use is made of Underspecification Theory: since the feature [voice] plays no distinctive role among the Toba Batak nasal consonants, this feature should not be taken to play an active role in these Toba Batak assimilations. Thus it appears that Hayes's argument in no way forces us to adopt a class node containing the laryngeal features and the feature [nasal], and hence that feature geometry need not be reviewed on this score.

25. Cf. Creider (1986) for some discussion of the use of n-ary features.

26. It is not the case that we are dealing here with the problem of creating a three-way distinction, since of the three classes two are already distinct in terms of some other property. Hence we cannot use the three-way distinction to make a segment B, non-distinct from two distinct segments A and C, distinct from both A and C. In other words, (43) does not involve LEXICAL DISTINCTNESS of zero. We will refer to this use of zero as the DERIVATIONAL DISTINCTNESS of zero.

27. Note the use of the term "complement rule". Archangeli & Pulleyblank allow the possibility that in a particular language the lexical value of some feature is in fact what would be the default value on universal grounds. In such cases we do not want the usual default rule to apply, because all segments would end up having the same value. Instead, in such a case we need a reversed default rule, which Archangeli & Pulleyblank call a complement rule.

28. The ROC recaptures a point made in McCawley (1968:40-43) in response to Stanley (1967). McCawley argues that only those redundant values which are of consequence to later rules must be filled in prior to the application of those rules.

Steriade (1987b) provides examples of rules which are ordered before a redundancy rule inserting [αF], although they refer to this value. To the extent that cases of this type are convincing they constitute empirical empirical evidence against the ROC as formulated by Archangeli & Pulleyblank.

29. Instead of [back] we could use [round]. The choice here is arbitrary. This freedom might be necessary (cf. Schane 1973), although we tend to regard it as a drawback of the feature system.

30. A difference between the statements in (46a) and the two in (46b) is that the former is a logical truth, whereas the latter are contingent truths, i.e. the former would not be true if the vowel system contained, say, /æ/, but the former is true due to the way the features are defined. One might argue that such logical truths point to a flaw in the feature system, but we will ignore this point here.

31. We cannot extract [–low] for /o/, because the required RR is false. This can be shown by checking the statements one arrives at via MTT:

$$\begin{array}{llll} [\text{–high,+back}] \rightarrow [\text{–low}] & \dashv\vdash & [\text{+low, +back}] \rightarrow & [\text{+high}]\ \text{F} \\ & \dashv\vdash & [\text{+low, –high}] \rightarrow & [\text{–back}]\ \text{F} \end{array}$$

Put differently, /o/ must be specified as [–low], because otherwise /a/ and /o/ would be non-distinct (cf. Clements 1987b). Note incidentally that if we take the feature [round] instead of [back] /e/ rather than /o/ ends up with three specifications (cf. Clements 1987b).

32. We retain the logical possibility of representing one segment as completely unspecified. So in any vowel system, one of the vowels can be represented in terms of the empty feature set. One might see this as the only possible instance of default feature assignment. Anderson & Durand (this vol.) make use of this type of underspecification. We ignore this possibility here. Another analysis of the same data, not resting on complete un(der)specification, is offered in Van der Hulst & Den Dikken (1987), briefly recapitulated in Van der Hulst (this vol.).

33. The reason why we concentrate on the vocalic features here is that most proponents of single-valued feature theories have based their arguments mainly on the analysis of vowel systems and processes affecting vowels.
34. Actually DP also allows for the representations in (i), apart from the ones given in (64). These representations appear to be superfluous as well, however.

(i) *Non-occurring possible DP representations*

*{|u;a,i|}	*{|a,u;i|}
*{|i;a,u|}	*{|a,i;u|}

Again there are no theory-internal reasons why these representations should be superfluous.
35. Notice here at once a parallel and a difference with the system of DP. Whereas DP does not claim that their primitives, called components, contain separate feature matrices, they do look upon them as individually pronounceable units, just as in CP.
36. Notice that [I]/[U] line fusion effectively changes a tridirectional feature system into a bidirectional one: the height and back/round dimensions are collapsed.
37. Notice also the significant definitional overlap of the DP features $|\alpha|$ "ATR" and $|r|$ "retracted tongue root (RTR)", the former being exclusively used for vowels and the latter for (pharyngeal(ised)) consonants. Thus there is actually a two-way redundancy in the DP system: cross-segmentally, $|\alpha|$ and $|r|$ define the same articulator, and within the vowel system $|\alpha|$ and mutual dependency both define the height dimension.
38. In addition to the five vowel elements in (72) there is also an element [N] "nasality" in the CP system. This element is taken to have positive charm.
39. This amendment of the charm system of CP does not solve a conspicuous problem associated with the element [N], which, as said in fn. 38, has positive charm and is hence predicted not to be combinable with [A], which is also positively charmed. Yet, it turns out that low vowels are exquisitely fit to be nasalised. Possibly, then, it is wrong to assign positive charm to [N]. We will leave this point open.
40. As appears from the representation ((A+.v–)-.ATR+)+, the element ATR plays a special role with respect to the property of charm in CP. As we mentioned earlier on, in general the charm of a compound expression is the charm of its head. In the above case, the compound expression has positive charm. Yet, the ATR element, which is the only element that can be responsible for this positive charm, is not the head of the compound: ATR on the whole never functions as a head. This indicates, then, that any compound expression containing ATR will be positively charmed, even if the head of the compound has negative charm. As Kaye, Lowenstamm & Vergnaud (1985:312) point out, the ATR element "functions as if its hot feature were positive charm... [it] acts like a pure charm operator with the property being expressed phonetically as ATR-ness". Its behaviour with respect to charm is another respect in which ATR is marked in the CP system, then.
41. This section draws on section 2 of Van der Hulst & Van Lit (1987).
42. Cf. Ladefoged (1982) for this type of definition of the major class features discussed in this section.
43. SPE has, in addition, a feature [syllabic], to differentiate between vowels and glides, but it is now generally agreed upon that this difference results from the syllabic organisation.
44. Clements, who uses a feature [vocoid] instead of [consonantal], arrives at the following fully specified representation (we ignore the [+/– syllabic] distinction, which he includes):

(i)

	O	N	L	V	
[voco]				+	
[appr]			+	+	
[son]		+	+	+	
	0	1	2	3	relative sonority

In this way relative sonority can be derived by counting the + values, i.e. the marked values are literally marked plus. This is not an essential point.

45. Clements notes the hierarchical relation among the major class (MC-) features, and he states that the sonority hierarchy can be derived from this, but he does not conclude from this that counting marked values is not what is relevant.

46. Clearly, this approach depends essentially on the use of a feature [appr]. One might suggest that nasals and liquids plus vowels could be kept apart in terms of the feature [continuant], thus making it unnecessary to introduce an extra feature. In fact, it has been argued that the sonority hierarchy can be derived from the major class features, including [continuant], in Basbøll (1977). However, we now run into a problem with the specification of fricatives. Because fricatives are [+continuant, –sonorant] we cannot predict the value for [sonorant] on the basis of the specification for [continuant], as we could on the basis of [approximant]. We have to speficy liquids as [+continuant], and predict the remaining values of [sonorant] on the basis of [–consonantal]. This means that we have destroyed the basis for deriving sonority from some independent property of the system, be it counting of (literally) marked values or looking at the hierachical level of the specified feature, or both.

47. The dual interpretation is also present, to a certain extent, in DP: a governing |V| means [+sonorant], whereas a governed |V| means [+voice], but is it not clear what the difference is between a governing and a dependent |C| or between a governing and a dependent |C:V|. Also, in this area but not, for instance, in the area of vocalic features, DP allows for a feature to dominate itself (albeit in the presence of another dependent feature).

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