A Two-Root Theory of Length

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In earlier versions of autosegmental theory the feature content of a segment was represented on a melody tier. The quantity of a segment was represented on a skeletal tier composed of so-called timing units--C's and V's, or simply X's. Long segments were single melody units doubly linked to the skeletal tier:

(1) Skeletal Tier   V V C C
                      \ / \ / \\
Melody Tier           a  b

In this paper I want to consider the implications for the autosegmental theory of length of two recent developments in the theory of phonological representation. The first development concerns the representation of the melody, the second concerns the skeleton. These theoretical developments require us to examine the representation of geminates with new eyes, and call for the elimination of the skeletal tier in phonological representation.
The 'melody' portion of a segment is no longer viewed as a simple distinctive feature matrix. Rather, features are now understood to be organized into a structured representation, one which has been referred to as feature geometry, following Clements (1985). Clements proposes that within the feature structure of a segment a root node dominates all other features that specify a segment. It is via the linear ordering of roots that the features of phonological representation are given a temporal organization (see Sagey 1986, 40ff). Following McCarthy 1988 I will assume that the root node is made up of the major class features Consonantal and Sonorant, so that we have vocalic roots, consonantal roots, obstruent roots, etc., as shown in (2):

(2) RV: [-cons] Robst: [+cons]
    [+son ] [-son ]

RC: [+cons] Rson: [ucons]
    [ucon ] [+son ]

And I will assume for the moment the feature organization in (3), again following McCarthy 1988:

(3)

The theory of feature structure that I will assume in this paper corresponds most closely to this conception. I should point out that whether "Place" stands for the Place node of feature-geometric theories or for the primary place feature, which dominates all other place features in a no-class-node approach like Selkirk (1988, in preparation), is immaterial for the present paper.

The basic autosegmental assumption that phonological length involves a single melody unit linked to two skeletal positions has been carried over in all recent work on feature organization (see e.g. Clements 1985, Sagey 1986, Schein and Steriade 1986, Archangeli and Pulleyblank 1986). These feature-geometric accounts assume that it is a single root node, rather than a monolithic melody unit, that is linked to the two skeletal positions guaranteeing length.
A TWO-ROOT THEORY OF LENGTH

Parallel to developments in the theory of feature structure, there have been important developments in the theory of the skeleton. The pioneering work of McCarthy 1979, 1981 on Semitic templatic morphology showed the necessity of separating the representation of a skeleton from that of the melody. In recent work, McCarthy and Prince 1986, 1988, 1990 have argued that the skeleta of templatic morphology are constituted solely of prosodic constituents, e.g. foot, syllable, mora. The claim is that no use is made in templatic morphology of a skeletal tier composed of C, V, or X. This paper provides support for the notion that there is no skeletal tier in phonological representation, in showing that it has no role in the representation of geminates.

Let us assume the McCarthy-Prince notion of the skeleton as constituted, in its lower reaches, by a syllable and mora structure, and lacking any representation of a skeletal tier. And let us assume the feature structure sketched above. Putting together the representations defined by these two theories, one sees that the root tier forms the interface between feature structure and the prosodic structure of the skeleton:

(4) The prosodic structure-feature structure interface

```
  Syl
     \m
      RC RV
   \   \  
  Other features
```

Now the question is: What is the representation of length in this prosodic structure-feature structure framework? There are two logical possibilities. The first, attributable to Hyman 1985, McCarthy and Prince 1986 and Hayes 1989, to appear, is a one-root theory of length, whereby a single root node is doubly-linked to two different positions in a syllable-mora structure.
(5) A One-Root Theory of Length

(Hyman 1985; McCarthy & Prince 1986; Hayes 1989, to appear)

Geminate Vowel  Geminate Consonant

\[
\begin{array}{c}
\text{Syl} \\
\text{.... m m ....} \\
\text{RV} \\
\text{Place}
\end{array}
\quad \begin{array}{c}
\text{Syl} \\
\text{.... m} \\
\text{Syl} \\
\text{RC} \\
\text{Place}
\end{array}
\]

One-root theory continues in the autosegmental tradition assuming that length involves a single 'melody' node linked to two skeletal positions: the melody unit is a single root node and the double links are to positions in syllable/mora structure, now the characterization of the skeleton. As articulated by McCarthy-Prince and Hayes, one-root theory is moreover a moraic theory of length. McCarthy-Prince and Hayes propose that in lexical representation long segments consist of a single root node linked to a single mora, and that the double-linking of (5) is produced by general rules of syllabification. This proposal makes predictions about the distribution of geminates and their behavior with respect to quantity-sensitive phenomena that will be examined below in sections 4–6.

An alternative, which I would like to argue for here, is a two-root theory of length. According to this theory, geminate entities involve two identical root nodes and some amount of shared feature specifications, including, crucially, shared features for Place, as shown in (6):

(6) The Two-Root Theory of Length

\[
\begin{array}{c}
\text{RV} \\
\text{RV} \\
\text{Place}
\end{array}
\quad \begin{array}{c}
\text{RC} \\
\text{RC} \\
\text{Place}
\end{array}
\]

The double-linking of place features shown in (6) is common to all geminates, full or partial. Full
The two-root theory in (6) differs from one-root theory in representing the notion 'segment' within the feature structure of phonological representation. The segment count of a representation is identified with the root count, not with the number of positions in (or, more precisely, associations to) syllable-mora structure. On this theory it is the root tier that is the 'timing tier', if by 'timing tier' we mean the tier giving the segment count of the utterance. Geminate vowels and consonants consist of two (root) segments. From the point of view of the theory of phonological representation, two root theory could be seen as a revision of the early autosegmental theory in (1) where features of the melody are associated to two positions in a C/V tier or X tier. What distinguishes the present conception of the root tier from earlier conceptions of the C/V or X tier is that root nodes are understood to be part and parcel of the feature organization of the representation. The root is itself comprised of feature specifications, and the relations of these with other features in the representation is arguably governed by quite general constraints on feature representation (on this, see section 3 below). On this view the C/V tier of (1) is a proto-root tier, and properly belongs to feature structure.

In what follows I am going to present three arguments from melody phenomena, i.e., from phenomena having to do with feature structure, in favor of representing length with two root nodes, as in (6), instead of as in (1) or (5). At issue are the splitting of geminates by laryngeal fission, long vowel diphthongization, and the nature of geminate inalterability.

The lexical representations of two-root theory, in (6), themselves make no commitment as to the status of geminate vowels and consonants in a syllable/mora structure. The moraification and syllabification of geminates is presumed to be accomplished by general principles and rules in the grammars of individual languages, and hence the moraic status of geminates might vary from one language to another. In this way, two-root theory
makes potentially different predictions from one-root theory. In the second part of the paper I will try to sort out where the one-root and two-root theories crucially diverge in their predictions about the behavior of geminate entities with respect to syllabification and quantity-sensitive phenomena by looking at compensatory lengthening, the distribution of geminates in syllable phonotactics, and the role of consonantal geminates in stress systems.

TWO-ROOT LENGTH AND FEATURE STRUCTURE

1. Laryngeal Fission

The first argument for a two-root theory of length is due to Steriade. In an unpublished paper Steriade (1987a) presents evidence for the existence of rules which modify the feature content of just one half of a geminate, leaving the other half with different feature content, or no feature content at all. The phenomena Steriade examines involve laryngeal features, where the two halves of geminates are differently specified for voice, glottalization, or aspiration. I'll refer to these as instances of laryngeal fission. Viewed in theory-neutral terms, the existence of laryngeal fission is simply an argument that the representation of geminates contains two sequentially ordered positions of which distinct laryngeal feature specifications could be predicated, but it does not indicate where in the representation these two sequentially ordered positions lie. One option would be to assign the different laryngeal feature specifications to constituents of prosodic structure. Allowing this would violate the generalization that the root node of a segment dominates all the features that characterize that segment. I suggest we make this a principle, call it the Principle of Skeleton-Melody Separation, written in (7), and use it to rule out the possibility of assigning features to moras or syllables.

(7) Skeleton-Melody Separation

The root dominates all features that specify a segment.

The reasons for adopting this principle are, first, that known generalizations about feature geometry not only conform to it, but probably depend on it,
and, second, that it restricts the set of possible representations in a desirable way.

Given skeleton-melody separation, there are two options for representing double laryngeal specifications for geminates in the prosodic structure-feature structure framework. According to one, a geminate has two root nodes, and each could become separately specified for laryngeal features. This is the analysis I will argue must be adopted. The alternative one-root theory of the geminate would require that the dual laryngeal specifications be assigned to a single root node. I will argue that this one-root solution is not a viable option, and thus that laryngeal fission gives support for a two-root theory of length. The two-root solution I am proposing to the problem of laryngeal fission is, from the point of view of the theory of phonological representation, a terminological variant of Steriade's (1987a) solution. Steriade assumes the existence of a C/V skeletal tier, and that geminates involve double-linking to two units of the C/V tier. The problem of laryngeal fission is solved by assuming that there is no root tier, and that the class nodes for laryngeal, place, and nasality features all directly link to the C/V tier. In the Steriade proposal the C/V tier in effect takes on the function of the root tier in feature representation. One could just as well understand Steriade as proposing that the C/V tier be abolished in favor of the root tier and that the root tier be the locus of the double-linking of geminates, as in my two-root proposal.

A particularly interesting case of laryngeal fission comes from Klamath (Barker 1964, Kingston 1985). Consonant length is contrastive in Klamath. Obstruents in Klamath are phonemically voiceless, glottalized and voiced: p t c k q ; b d j g G ; p' t' c' k' q'. Within the rime, however, this distinction is neutralized. Following Kingston and Steriade, I will assume there is a rule of laryngeal neutralization, which delinks any laryngeal feature from an obstruent in a rime, leaving it unspecified.
(8) Klamath Laryngeal Neutralization

Rime

Robst

Laryngeal

Assume that a default rule later fills in the voiceless plain value observed in this position. When the rule applies to a heterosyllabic obstruent cluster, it will produce a derivation like that in (9).

(9) Nongeminate obstruent clusters: p'k --> pk,

      dk'--> tk',

etc.

Robst Robst

Place_p Lar_j

Robst Robst

Place_q Lar_j

What's of interest is that the neutralization rule affects the first half of geminate consonants, too, creating a long consonant with a sequence of two different laryngeal specifications, as shown in (10).

(10) Geminate obstruents: p'p' --> pp', dd --> td,

etc.

Robst Robst

Place Laryn

Robst Robst

Place Laryn

This happens with underlying geminates, as well as with geminates that are created through reduplicative gemination, or through morphological concatenation. Consider for example the geminate-producing reduplicative morpheme meaning 'intensive action or state'. When it is an obstruent that gets doubled, the result is a geminate with laryngeal fission, e.g. [god1:la] 'goes under' vs. [gotdi:la] 'goes around under'. The point, then, is that all heterosyllabic obstruent clusters in Klamath, whether geminate or not, are laryngeally split.
This is straightforwardly representable with a two-root theory of the geminate.

Let us consider now how a one-root theory of the geminate would fare with Klamath. Given skeleton-melody separation, one-root theory will require the two different laryngeal specifications in geminates to be assigned to the same root node:

(11) \[
\begin{array}{c}
\text{Syl} \\
\downarrow \\
\text{m} \\
\downarrow \\
\text{Robst} \\
\downarrow \\
\text{Laryn} \\
\downarrow \\
[-\text{voice}] [+\text{voice}]
\end{array}
\]

(To make this solution workable for Klamath, the default laryngeal state 'plain voiceless' would have to be specified for the default [-voice]. Otherwise there would be no double specification.) The problem with (11) is that it fails to indicate that it is the part of the geminate that is in the rime which is realized as plain voiceless. How is such a representation interpreted in current feature theory? If the analogy is to segments like labiovelars with multiple place articulations (discussed by Sagey (1986)), then both halves of the geminate in (11) would be realized with both laryngeal values. This would be wrong. Suppose instead the analogy is to affricates. In affricates two contrasting specifications of the feature [continuant] are attached to the root node, and are pronounced in the order stop-fricative. Lombardi (1989) shows, however, that the ordering within affricates cannot be phonological. Rather it must be introduced late in the derivation. Moreover, since the ordering is always the same, it is plausibly introduced by universal principles. In other words, putting together the results from Sagey and Lombardi, there is no independent basis for assuming that an ordering of feature specifications is possible under the root node. This important characteristic of feature structure could be named as follows:
The No-Feature-Ordering Generalization

Features dominated by the same root node are not phonologically ordered.

The one-root solution to laryngeal fission in (11) violates this generalization. This problem would be obviated if universal principles could be called on to guarantee the proper ordering of the two laryngeal specifications in geminate obstruents (see Kingston 1985). Yet we are still left with the necessity of seeing the ordering of the laryngeal features in geminates and nongeminates in different terms. And that is really the essential drawback.

(Danish provides a parallel example of laryngeal fission with long vowels. Syllables with a stød locate this glottalization on the second half of a long vowel, or on a syllable-final sonorant consonant following a short vowel (Basbøll 1988).)

Icelandic preaspiration (Thráinsson 1978a, 1978b) represents another case of geminate laryngeal fission. Again, I follow Steriade in concluding that the phenomenon requires a representation of geminates as doubly-linked to two feature-attachable nodes. As Thráinsson 1978, Steriade 1987a, Hermans 1985 and Kingston 1990 make clear, preaspiration is by no means a phenomenon restricted to geminates. Rather, it involves the delinking of aspiration [{+[spread glottis]} from an underlying aspirated stop and a transfer of that aspiration to the preceding consonantal segment, producing voicelessness (see also Einarsson 1927, 1967; Petursson 1972). In southern dialects, for example, all sonorant plus aspirated stop sequences turn into a voiceless sonorant plus unaspirated stop sequence. The derivation Steriade 1987a proposes for such cases is given in (13).

\[
\text{(13) } /lp^h/ \rightarrow [lp]
\]

Preaspiration in geminates involves a somewhat more dramatic effect. The gemination of aspirated stops gives rise to a sequence of h plus unaspirated stop: /pp^h/ \rightarrow /hp/. Still following Steriade, the transfer of [{+[spread]} to the initial half of a
geminate (in our terms, to the initial root of the geminate) is followed by a delinking of the place features, creating the $h$ plus stop sequence:

(14) \[ /pp^h/ \rightarrow [hp] \]

The essential point is that a two-root representation of the geminate stops permits preaspiration in geminates to be subsumed under the more general phenomenon of preaspiration in consonant clusters. Whereas with a one-root theory of geminates it becomes a mystery why geminates should pattern with consonant sequences.

What would the derivation look like with a one-root theory? Somehow, the two differently featured segments of the surface form have to be derived from a single root source. (15) shows the presumed beginning and endpoints of the derivation:

(15) \[ /pp^h/ \rightarrow [hp] \]

How is this operation to be generalized with the more banal transfer of [+spread] from root to root in (13)? And what sort of operation is this in the first place? (On this question see Iverson (1989).) Even supposing the theory were to countenance meiotic division of this sort, what assures that the features end up where they do, with [+spread] on the first new root and the place features on the second. The one-root theory of the geminate raises more questions than it answers here.

Clements (1985) discusses Icelandic preaspiration. Though he in general assumes a one-root theory of geminates, he adopts a two-root theory of the Icelandic geminate in order to give expression to this laryngeal splitting. In the
theory of length I am proposing here such options are not available. Length is always a matter of two root nodes.

2. Diphthongization

The two-root theory of length has been so far motivated as a response to the problem of laryngeal fission in consonantal geminates that would preserve intact the generalization that features (or nodes) dominated by the same root node are not phonologically ordered, cf. (11). Hayes to appear responds to the same class of problems with a proposal which allows for a limited set of violations of the No-Feature-Ordering Generalization. His proposal allows that two features dominated by a single root node may be ordered just when the root node is itself associated to two positions in the skeleton. An indexing notation is introduced to allow for formal expression of the dependency of feature ordering on ordering in the skeleton. It is illustrated in (16):

(16)  
\[ \begin{array}{c}
  X_i \\
  \downarrow \\
  \text{Root}_{i,j} \\
  \downarrow \\
  \text{Laryngeal}_{i,j} \\
  \downarrow \\
  [-\text{voice}]_i [+\text{voice}]_j 
\end{array} \]

(Hayes suggests that it makes no difference whether the positions in the skeleton to which the root node is doubly linked are units of the C/V or X skeletal tier or units of syllable/mora structure. We will see below that in the theory he proposes, those positions must be located in the skeletal tier.) The Hayes proposal is that positions in the skeleton and the features and nodes of feature structure all bear indices; these indexations are governed by a principle of percolation such that a feature or node must share an index with a root node that dominates it, and the root shares indices with each of the skeletal positions to which it is linked. Thus if the root node is associated to two skeletal positions \( X_i \) and \( Y_j \), it may dominate two ordered features, each one indexed for \( i \) and \( j \) respectively, as in (16). The order of the phonetic realization of the features is governed by
the order of the coindexed positions in the skeleton. The Hayes theory thus predicts that no ordering is possible among features or nodes dominated by a root that is associated to a single skeletal position. In that it coincides with the predictions of the No-Feature-Ordering Generalization. But it predicts that in geminates, where a single root node is associated to two skeletal positions, ordering is possible, amongst any features or nodes, even those not immediately dominated by the root node. In this it contrasts with no-feature-ordering theory, which allows two features or nodes to be ordered only if they are dominated by distinct root nodes.

Hayes sees vowel diphthongization as providing crucial evidence against a no-feature-ordering account, precisely because he assumes that the vowel place features which are ordered in diphthongization are "deeply embedded within the tree", and hence are not dominated by distinct root nodes. Let us consider a concrete example, the rather commonplace diphthongization of e: to eI and o: to ou, such as in Old French, discussed by Hayes. Hayes assumes a feature geometry of the Clements or Sageyan type, in which place features are dominated not only by the class node Place but also the class node Supralaryngeal. And he assumes a theory of vowel features which is inspired, in part, by the particle theory of Schane (1984) and others. Particle theory ascribes the following particle representations to vowels:

\[(17)\]

\[
\begin{align*}
/i/ &= \text{I} \\
/u/ &= \text{U} \\
/e/ &= \text{IA} \\
/o/ &= \text{UA} \\
/a/ &= \text{A}
\end{align*}
\]

Adopting this view of the vowel particles, long e: would be assumed by Hayes to be represented as in (18), where the single root node is coindexed with both skeletal positions to which it is associated, and all the features and nodes dominated by that single root share both of its indices:
Given the Hayes indexing theory, vowel diphthongization is a matter of manipulating particles and their indices. Specifically, $e_i$ can be derived from $e_i$ in (18) by depriving the A particle of the index $i$, which corresponds to the second skeletal position. This gives rise to an ordering of feature indices within the vowel—$A_i I_j$ ($= e_i$) followed by $I_j$ ($= i$), in other words, a diphthong. Of course, this argument from vowel diphthongization against no-feature-ordering stands only insofar as the above assumptions about the representation of place features in feature organization hold up, and I believe they do not, as we shall see.

But suppose for the sake of argument that Hayes's assumptions about the representation of place do hold up, such that some version of ordering by coindexation is required in the theory. What are the implications of this for the argument I have mounted, following Steriade, for a two-root theory of length? The Hayes argument is that if ordering by coindexation is part of the theory of phonological representation, there is no motivation for a two-root theory of length. The argument does not go through, however. In the present section I show that a two-root theory of vowel diphthongization is preferable to a one-root theory of the phenomenon.

Consider a two-root approach to vowel diphthongization which makes the same assumptions about feature structure as in the approach in (18). The representation of $e_i$ would be as in (19a) and the diphthongization to $e_i$ would be as in (19b).
The correlation of feature ordering with length that the Hayes theory tries to capture could now be understood as a correlation of feature ordering with number of root positions, instead of with number of skeletal positions, obviating any necessity for extending indexation to positions in the skeleton. Therefore, one advantage of the two root theory of the diphthong is that it would permit a more restrictive theory of indexation, one which would confine indexation to the nodes and features of feature structure, and in this way respect the spirit of the principle of skeleton-melody separation. This is the first argument for a two root theory of vowel diphthongization.

But is the feature structure in (18) and (19) well-motivated? Are we really forced to think of place features as being so "deeply embedded within the tree" that some kind of feature-ordering-by-coindexation is required? I believe the answer is no. McCarthy (1988) presents arguments against the Supralaryngeal node. In Selkirk (in preparation) I argue against the existence of the Place node. And in Selkirk (1988, in preparation) I argue in favor of a dependency representation between features for place, in the sense of Mester (1986, 1989). So assuming the same vowel place feature particles as in the preceding treatment, and assuming a two root theory of length, the representation of long `e` would be as in (20a), and the outcome of diphthongization could be represented as either (20b) or (20c):

(20) a. RV RV    b. RV RV    c. RV RV
\ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        \ /        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the nonprimary vowel feature (here I) to the newly placeless root node, as shown in (20b), banal operations in the current theory. The nonhomogeneous linking in (20b) could conceivably give rise to the non-doubly-linked representation in (20c), by mitosis. (Note that (20c) does not show an OCP violation, since primary and secondary vowel features are not feature-adjacent (see Selkirk 1988, in preparation).) In (20b) or (20c) the ordering of features is achieved simply through direct domination by successive root nodes. Thus the theory of feature organization assumed in (20), in conjunction with two root length, makes ordering by coindexation superfluous. If these assumptions about feature organization do indeed prove well-founded, the argument from diphthongization for a two root theory of length is even stronger than in the preceding paragraph. In this case a two root theory of length would allow for feature ordering to be eliminated entirely from feature structure, as specified in the No-Feature-Ordering Generalization, (11). The argument, then, is that with either set of assumptions about feature structure, the two root theory of length allows for a more restrictive theory of feature ordering in phonological representation. Whether feature ordering can be eliminated entirely, as would be allowed by the newer assumptions about the location of place features in feature structure, is a question that will be left open for the time being.

The second argument from diphthongization for a two root theory of length is based on the fact that short diphthongs require a representation distinct from long diphthongs. Hayes claims that diphthongs only arise from long vowels, and that in the unmarked case diphthongs count as long from the point of view of quantity. He shows how one-root theory would predict this. Actually, both the one-root and the two-root theories of diphthongs sketched above predict this. With two root theory (in either of the versions sketched) the feature ordering in diphthongs can only arise in a structure with two root nodes, and long vowels have this property. Thus diphthongs could not arise from short vowels. Moreover, in two root theory a diphthong would normally be represented as bimoraic, or long in quantity. This is because, in the unmarked case, each vocalic root node in a representation is moraified, whether a short vowel or part of a long vowel, a diphthong, a sequence of vowels:
(21) a. short  b. long, diphthong, or sequence

a. short  b. long, diphthong, or sequence

(On principles of syllabification and moraification in two root theory, see section 6.) What now of the representation of short diphthongs? Hayes claims that short diphthongs arise historically from original long diphthongs, and that they are rare, i.e., highly marked. Let us assume that what it means for a diphthong to be short is that it is monomoraic. Within a two root theory of diphthongs, the difference between short and long diphthongs would be represented at the feature structure-prosodic structure interface, as in (22).

(22) Two root theory of diphthongs

Both long and short would have two distinct root nodes, RV_i and RV_j. But whereas in the former each root is moraic, in the short diphthong both root nodes are linked to a single mora. Such structures are in principle possible in two root theory, but marked, since, as we said, in the unmarked case each vocalic root node would be separately moraified.

How would a one root theory of diphthongs of the sort Hayes describes represent the difference between long and short diphthongs, assuming that the latter are monomoraic? Recall that in the ordering by coindexation theory proposed by Hayes feature ordering in diphthongs is possible only if there are two distinct positions in the skeleton to which the single root node of the vowel diphthong is linked. Therefore, both short and long diphthongs must be represented with two distinct positions in the skeleton. But those two distinct positions cannot be moras, since short diphthongs are assumed to be monomoraic. What could those positions be? It might seem to be an option to assume that the single root node of a short diphthong is linked both to a single mora position
and to the syllable node, as in (23b):

(23) One root theory of diphthongs— Version I

a. long diphthong  
\[ S \]
\[ \begin{array}{cc}
 m_i & m_j \\
 R_{t_i,j} \\
 \end{array} \]

b. short diphthong  
\[ S_j \]
\[ \begin{array}{c}
 m_i \\
 R_{t_i,j} \\
 \end{array} \]

But this option is ruled out since the \( i,j \) positions in the skeleton in (23b) are not temporally ordered, and therefore the ordering of features in the diphthong could not be derived by coindexation. The only other option appears to be to assume the existence of an additional skeletal tier in phonological representation, a revival of the C/V or X tier which this paper is arguing can be eliminated. This tier would mediate between the root nodes of feature structure and the mora and syllable nodes of prosodic structure and provide the basis for the ordering of short diphthong features through coindexation, as in (24b).

(24) One root theory of diphthongs— Version II

a. long diphthong  
\[ S \]
\[ \begin{array}{cc}
 m & m \\
 X_i & X_j \\
 R_{t_i,j} \\
 \end{array} \]

b. short diphthong  
\[ S \]
\[ \begin{array}{c}
 m \\
 X_i & X_j \\
 R_{t_i,j} \\
 \end{array} \]

The point then is that assuming a one root theory of diphthongs requires this extra-rich theory of phonological representation, while a two root theory of diphthongs permits the skeletal tier to be done away with. This is obviously an argument in favor of a two root theory of diphthongs, and of a two root theory of vowel length, if there is no independent motivation for this extra skeletal tier.

To sum up, two arguments have been made for a two root theory of length on the basis of vowel diphthongization. The first is that it allows for a more restrictive theory of feature ordering than
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a one root theory does. The second argument is that two root theory permits one to maintain the theory of the prosodic structure-feature structure interface given in (4), which lacks the arguably otiose C/V or X skeletal tier.

3. The Nature of Geminate Inalterability

It is by now a well-known fact that geminates may fail to be affected by certain phonological rules which would alter the featural content of segments. For example, the rule spirantizing postvocalic stops in Tiberian Hebrew does not apply to geminate stops:

(25) Tiberian Hebrew postvocalic spirantization

a. melex (<melek) malka
   'king'       'queen'

   mixtav (<miktab) kaatav
   'letter'       'he wrote'

b. giddel gadal
   'he brought up, educated'

   libbi levavo.t
   'my heart'     'hearts'

   levavot

(Underlining indicates spirantization.) This inalterability of geminates has been quite generally attributed to their representation as a doubly-linked structure (Steriade 1982, Hayes 1986, Schein and Steriade 1986). The influential treatments of geminate inalterability by Hayes and Steriade and Schein understand it to be the consequence of a constraint which restricts the applicability of a rule to a representation. In this section it will be argued instead that cases of geminate inalterability are a consequence of properties of the phonological representation itself. Specifically, it will be argued that three distinct elements of the theory of phonological representation combine to give geminate inalterability as a result. These are (i) the theory of the organization of features (aka feature
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geometry), and more specifically the assumption of Place-Stricture Dependency, (ii) the two-root theory of length, and (iii) a general constraint on multiple linking within feature structure.

McCarthy 1988 does away with a number of the class nodes of earlier feature geometry and posits the feature organization in (2) and (3), given above. In the McCarthy proposal, Place is directly dominated by the major class features [sonorant] and [consonantal]. Evidence that I will present below supports this dependency of Place on the stricture features of the root node. But we will see moreover that there are good reasons for assuming that when a segment is specified for the feature [continuant], Place is dependent on the feature [continuant], rather than on the root. The hypothesis that Place depends on the stricture features in this way I will refer to as Place-Stricture Dependency:

(26) Place-Stricture Dependency:

a. Place is dependent on the feature Continuant.

b. In the absence of Continuant, Place is dependent on the root node, analyzed as a complex of the features Consonantal and Sonorant.

The picture of feature organization that will emerge is therefore that in (27):

(27) Feature Structure incorporating Place-Stricture Dependency

```
Root
@cons
%son

(&cont)

Nasal  Place  Laryngeal
```

As for the representation of length, I proposed above that the length of geminate consonants and vowels is represented within feature structure, with two root nodes. The proposal made above in (6) must be elaborated slightly in view of Place-Stricture Dependency. I will assume geminate vowels are represented as in (28a), geminate
A TWO-ROOT THEORY OF LENGTH

consonants without a [continuant] specification are represented as in (28b), and those with a [continuant] specification are as in (28c):

(28) The Two-Root Theory of Length

Geminate Vowel

\[\begin{array}{c}
\text{Root} \\
-\text{cons} \\
+\text{son} \\
\end{array} \quad \downarrow \\
\begin{array}{c}
\text{Root} \\
-\text{cons} \\
+\text{son} \\
\end{array} \quad \\
\text{Place}
\]

Geminate Consonants

\[\begin{array}{c}
\text{Root} \\
+\text{cons} \\
+/-\text{son} \\
\end{array} \quad \downarrow \\
\begin{array}{c}
\text{Root} \\
+\text{cons} \\
+/-\text{son} \\
\end{array} \quad \\
\text{Place} \\
\end{array} \quad \downarrow \\
\begin{array}{c}
\text{Root} \\
+\text{cons} \\
+/-\text{son} \\
\end{array} \quad \\
\text{Place} \\
\downarrow \\
+/-\text{cont} \\
\text{Place}
\]

Finally, it is generally assumed that any multiple linking in feature structure is subject to well-formedness constraints. These have been most notably articulated as constraints on the locality of multiple linking (Steriade 1987c, Archangeli and Pulleyblank 1986, 1987). In general, I think it can be argued that constraints on multiple linking have the form in (29):

(29) Multiple Linking Constraint (general form)

If \( G \uparrow F \uparrow H \)

then (i) \( G = H \) w.r.t. some property \( P \), and

(ii) There is no \( J \), s.t. \( J \) also has property \( P \) and \( J \) lies between \( G \) and \( H \).

What this says is that in a feature structure configuration where an element \( F \) is a multiply linked dependent of heads \( G, H \): (i) \( G \) and \( H \) are must be identical with respect to some property \( P \),
and (ii) G and H must be P-adjacent, that is, no other element with property P may intervene between G and H. (Def. A feature or node B is a dependent of a feature or node A iff A immediately dominates B. In this case, A is the head of B. (Mester 1986, 1989)) The formulation of this constraint on locality in multiple linking is closest in spirit to the notion of locality posited in Archangeli and Pulleyblank 1986, 1987.

As is well known, adjacency is a notion requiring parameterization (see Archangeli and Pulleyblank 1986, 1987; Steriade 1987c; Selkirk 1988; Odden 1990). It is implied by the formulation of the Multiple Linking Constraint in (29) that the parameters of adjacency amount to specifying what the relevant properties P are in universal grammar.

In the particular case where the heads of a multiply linked configuration are stricture features, there are reasons to think that, universally, the relevant dimension of identity, i.e. property P, is feature content. That is, identity of features seems to be required in such a configuration. I will call this constraint on linking to stricture features Homogeneous Stricture Linking:

(30) Homogeneous Stricture Linking (provisional)

\[ G H \]
\[ \text{If } \forall F \text{ and } G, H \in \text{(STR)}, \]
\[ \text{then (i) } G = H = \text{STR}_i \]
\[ \text{ (ii) No instance of } \text{STR}_i \text{ intervenes between } G \text{ and } H \]

\( \text{(STR)} = (+\text{cons}, -\text{cons}, +\text{son}, -\text{son}, +\text{cont}, -\text{cont}) \)

What this constraint rules out is any multiple linking to stricture features where the stricture feature specifications are not identical. The analysis of geminates given in (28) conforms to this constraint.

In what follows I will show first that assuming that geminate inalterability results from a constraint on multiple linking-- of whatever form-- allows a better theory of which types of
rules fail to show inalterability than either the Steriade and Schein (1986) or Hayes (1986) approaches. Then I will show that assuming Homogeneous Stricture Linking, along with the representational assumptions of two root length and Place-Stricture Dependency, allows us to narrowly characterize just which rules are subject to inalterability. Finally I will show that the same set of assumptions about the representation, together with Homogeneous Stricture Linking permit an explanation for why lenition and degemination should go hand in hand in some languages, a phenomenon which the Schein and Steriade (1986) and Hayes (1986) theories of geminate inalterability are quite unable to explain. Degemination will be argued to be a repair strategy, in the sense of Singh (1984) and Paradis (1988a, 1988b), a response to the creation of an ill-formed representation when a lenition process does apply to part of a geminate. In other words, it will be argued that while geminate inalterability is an instance of the blocking effect of a constraint on well-formed representations, degemination is an instance of the repair-motivating effect of a constraint on well-formed representations.

3.1 Geminate Inalterability and Constraints on Multiple Linking

If a constraint on multiple linking in feature structure—in whatever form—is responsible for the phenomenon of geminate inalterability, then only rules which would create an ill-formed multiple linking would belong to the set that could block when applying to geminates. One important prediction of this approach, therefore, is that rules which involve a delinking operation would never be blocked from applying to geminates. Delinking in a doubly-linked feature configuration would create at most a singly linked structure, which is of course compatible with any constraint on multiple linking, be it Homogeneous Stricture Linking or any other. The hypothesis that a constraint on multiple linking is at play in geminate inalterability also predicts that any rule which leaves the wellformed double-linking in geminates intact will fail to be blocked from applying.

Recall now the case of delinking in Icelandic which went by the name preaspiration. It is a
rule which delinks the feature [+spread glottis] from a consonant root that is preceded by another consonant root, as in (31):

(31) Icelandic preaspiration

\[
\begin{array}{c}
\text{Root} \\
+\text{cons} \\
\text{Root} \\
+\text{cons} \\
\text{+spread}
\end{array}
\]

As pointed out above, preaspiration is not restricted to geminates. Rather, it involves the delinking of aspiration ([+spread glottis]) from any underlying aspirated stop which follows another consonant and a linking of that aspiration feature to the preceding consonantal segment, producing voicelessness in that segment. In geminates it involves an additional effect, the delinking of place from the first half:

(32) 

\[
\begin{array}{c}
/\text{pp}^h/ \\
\text{RC}_i \quad \text{RC}_i \\
\text{---} \quad \text{---} \\
\text{RC}_i \quad \text{RC}_i \quad \text{RC}_i \quad \text{RC}_i \\
\end{array}
\]

\[
\begin{array}{c}
\text{Place} \quad [+\text{spread}] \\
\text{RC}_i \quad [+\text{spread}] \quad \text{Place} \\
\text{RC}_i \quad [+\text{spread}] \quad \text{Place}
\end{array}
\]

The fact that the delinking of [+spread] and of Place can apply in the case of geminates is explained under the approach I am proposing here, since these delinkings at no time create an ill-formed multiple linking in the phonological representation.

In comparison, both the Schein and Steriade (1986) and Hayes (1986) theories of geminate inalterability predict that delinking rules would block with geminates, unless the structural description of the rule explicitly mentions the double linking. The rule of preaspiration in Icelandic is not specific to geminates, and so does not mention any double linking. Therefore these approaches predict that the delinking of [+spread] should be blocked from applying to the lefthand representation in (32). Recall that both these theories understand geminate inalterability to be due to a condition on the applicability of a rule to a representation. The fact that delinking rules in general—be they rules delinking laryngeal features, or tone features, or features for place—
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seem not to be subject to geminate inalterability indicates that inalterability should not be traced to the structural description of a rule, as in the Hayes 1986 and Schein and Steriade 1986 theories.

The other class of rules that a constraint on multiple linking predicts should not be subject to geminate inalterabililty are rules that would alter any part of the representation of geminates that is not involved in the doubly linked configuration. Consider the two-root representations of geminate vowels and consonants in (28). Any rule which affected the features dominated by Place would do nothing to alter the wellformed double linking within these geminate representations, and so would never be blocked by the Homogeneous Stricture Linking principle. Examples of the application of such place-altering rules with geminates have been discussed in connection with the issue of inalterability. They include consonant palatalization in Luganda (Hayes 1986), final vowel lowering in West Greenlandic Eskimo (Hayes 1986), final a rounding in Javanese (Dudas 1976, Kenstowicz 1985, Steriade 1987b), various sorts of vowel harmony (Schein and Steriade 1986), and Sanskrit nati (Schein and Steriade 1986). These rules affect both simple segments and geminates alike, and thus behave as the general hypothesis given in (11/13) would predict. The Hayes Linking Constraint also predicts such rules should be free to apply to geminates, as long as their structural descriptions make no mention of the links of the Place node to the root tier. The Schein and Steriade UAC predictions are similar (though not identical). So on this score the multiple-linking constraint hypothesis makes much the same predictions as other current theories of geminate inalterability.

Consider for example the case of palatalization in Luganda.
Luganda palatalization (Hayes 1986, Clements 1986)

a. kiintu - ciintu 'thing'
bwoogi - bwooji 'sharpness'
oluggi - olujji (*olugji) 'door'

b. RC₁ RC₁ RV/G
   Place       Place
   \          \    
     -         -
   Coronal

Here the coronality of the high vowel i spreads to the preceding segment, palatalizing it. The rule is happily ignorant of whether "Place" is doubly linked or not, and so applies equally to geminates or simple segments.

To sum up, the hypothesis that I have been pursuing up to this point is that geminate inalterability is to be traced to a constraint on multiple linkings within feature structure. The predictions of this general hypothesis have been borne out so far. In contrast, the Hayes (1986) and Schein and Steriade (1986) theories fail to predict the behavior of delinking rules. They fail to explain why it should be that delinking rules may apply to doubly-linked structures such as are found with geminates.

2.0 Rules which may be blocked from applying to geminates

Let us consider next the predictions that a constraint on multiple linking would make about which types of rules are subject to blocking when applied to geminates. There is actually only one logical possibility, given the two-root representation of geminates in (28). Only rules that would alter stricture features, those features upon which the doubly-linked Place or [Continuant] are dependent, would have the capacity to create ill-formed multiple-linkings out of the well-formed ones in a geminate structure. And we will see below, in this section, that it is precisely rules that do introduce a change in stricture features that are subject to blockage with geminates. In the next section we will see that when a stricture-
feature-altering rule does apply to a geminate, its illformed output is submitted to a further change, an apparent case of a 'repair' motivated by a constraint on well-formed representations.

The Multiple Linking Constraint in its general form (29) requires that the heads in a multiply linked structure must be identical with respect to some property P. The more specific Homogeneous Stricture Linking (30) requires that in a multiple linking involving stricture features, the stricture features must be identical in feature content. Given Place-Stricture Dependency and the two root representation of geminates, Homogeneous Stricture Linking requires that the stricture features to which "Place" or [continuant] are linked in geminates must be identical. Therefore any rule which changes the value of the features [consonant] or [sonorant] in just one half of a geminate will give rise to a multiple linking that is illformed according to Homogeneous Stricture Linking, and such rules are predicted to be subject to blockage with geminates. Moreover any rule which results in a multiple linking of "Place" to opposite specifications of the feature [continuant] creates an illformed representation and is predicted to be subject to blockage. The predictions appear to be borne out. For example, the great majority of the rules showing geminate blockage that are discussed in the Hayes article turn glides into vowels, vowels into glides, obstruents into sonorants, sonorant consonants into vowels, or stops into continuants. (Churma 1988 underlines the importance of the fact that the rules showing inalterability are largely weakening rules.)

Consider the case of sonorantization in Hausa that goes by the name of Klinghenheben's Law, a case discussed by Hayes (1986). Historically, syllable-final consonants all became sonorants in Hausa, and there are also reflexes of this process in synchronic alternations (Klinghenheben 1928; Newman 1970; Schuh 1972, 1974; Venneman 1972):

(34) Klinghenheben's Law

a. velars - w

'left side' hawni / behago 'lefthanded one'
'poverty' talawcii / talaka 'poor person'
'a twin' batawayee / tag"ayee 'pair of twins'
b. coronals - r
'to count'  kirga / kидiddiga  'to reckon'
'merchant'  farke / fatake  'merchants'
'under'  k'ark'asин / k'asа  'earth'
'very fast'  marmaza / maza  'fast'

c. labials - w
'barking'  hawsii / hapsii  (dialectal)
'a blind one,  makawniya / makafo  'a blind one,
 m.'

The rule may be given the formulation in (35):

(35) Klingeneheben's Law in Hausa

\((\ldots \text{Root })\text{Syl} \rightarrow (\ldots \text{Root })\text{Syl} + \text{son}\)

I should say here that I am not assuming that the rule changes the +/-value of the feature [sonorant], but rather that it assigns, or adds, the property represented by the feature specification [+sonorant] to the coda consonant of a syllable, causing the deletion of any [-sonorant] specification that might be present. In general, it seems quite likely that the category of feature-coefficient-changing rules should be excluded from grammar. This becomes all the more likely, as more and more features turn out to be mono-valued. In the present paper, I am assuming for the sake of convenience the bivalency of stricture features, but want to formulate the rules, and constraints on representation, in such a way that they do not depend on this property.

Now, Klingeneheben's Law does not affect geminate consonants, though the first half of a geminate would satisfy the structural description of the rule:

(36)  tukkuu  'crest'
taffа  'ginned cotton'
buddari  'skunk'
babba  'a big one'

The explanation offered for this blockage by Homogeneous Stricture Linking is that the application of Klingeneheben's Law to a geminate obstruent would give rise to an ill-formed...
representation, with the Place or [continuant] feature doubly linked to root nodes with opposite specifications for the feature [sonorant]. The ill-formed representation is shown in (37), where F stands for either Place or [continuant]:

(37) Klingensheben's Law applied to geminate obstruents

\[
\begin{array}{c}
\text{Root} & \text{Root} & \Rightarrow & * & \text{Root} & \text{Root} \\
\text{[+cons]} & \text{[+cons]} & & \text{[+cons]} & \text{[+cons]} \\
\text{[-son]} & \text{[-son]} & & \text{[+son]} & \text{[-son]} \\
\lor & F & \lor & F \\
\end{array}
\]

The figures in (37) are intended to notationally represent the double linking of the dependent feature F to the complex of [sonorant] and [consonant] features that comprise the root node, not a double linking of F to the two instances of the feature [sonorant]. In other words, the nonidentity of the feature specifications for [sonorant] on the right in (37) is not directly responsible for the violation of Homogeneous Stricture Linking, rather it is the nonidentity of the entire root complex, which is assumed to be the head of F in (37), which is responsible for the illformedness created.

To make the status of the Root node in this configuration entirely clear, the set (STR) of stricture feature heads mentioned in the statement of Homogeneous Stricture Linking, (30), should be modified to include root complexes as members:

(38) Homogeneous Stricture Linking (revised)

If \( F \lor \) and \( G, H \in (\text{STR}) \),

then (i) \( G = H = \text{STR}_i \)

(ii) No instance of \( \text{STR}_i \) intervenes between G and H

\( (\text{STR}) = (+/-\text{cons}, +/-\text{son}, +/-\text{cont}, \text{Root}) \)

The other main body of rules which this theory predicts to be subject to blockage with geminates are rules which change the value of the feature [continuant]. Tiberian Hebrew postvocalic
spirantization, formulated in (39), is an example of this sort.

(39) Tiberian Hebrew Postvocalic Spirantization

\[
\begin{array}{c|c}
\text{Root} & \text{Root} \\
-\text{cons} & +\text{cons} \\
-\text{son} & \\
\end{array} \quad \Rightarrow 
\begin{array}{c|c}
\text{Root} & \text{Root} \\
-\text{cons} & +\text{cons} \\
\text{son} & +\text{cont} \\
\end{array}
\]

(The rule has the function of assigning the feature specification \([+\text{continuant}]\) to the postvocalic consonant; it is not a rule which merely changes the coefficient of any existing \([\text{continuant}]\) specification from '-' to '+', cf. discussion of (35).) Blockage in cases of spirantization would not predicted by Homogeneous Stricture Linking if the feature \([\text{continuant}]\) were simply a sister to the Place and Laryngeal nodes in feature structure, as in the McCarthy proposal in (3). But suppose we instead adopt the view in (27), where Place is dependent on the feature \([\text{continuant}]\) in feature structure, as called for by Place-Stricture Dependency, (26). This dependency is presupposed in the two root representation of geminates in (28c). A spirantization rule applying to just one half of a geminate would produce an ill-formed double-linking. An example of this is given in (40), which shows the effect of spirantization on Tiberian Hebrew geminates.

(40) 

\[
\begin{array}{c|c}
\text{Root} & \text{Root} \\
+\text{cons} & +\text{cons} \\
-\text{son} & -\text{son} \\
\end{array} \quad \text{I I} \\
\text{I I} \quad \text{I I} \\
\end{array}
\]

This is ruled out by Homogeneous Stricture Linking.

To sum up, the central cases of geminate inalterability all appear to involve rules which introduce alterations in the specifications of the stricture features \([\text{consonantal}]\), \([\text{sonorant}]\), and \([\text{continuant}]\). Any theory of geminate inalterability should provide an explanation for this fact. The explanation I am proposing relies on three assumptions about phonological representation: (i) that length is represented within feature
A TWO-ROOT THEORY OF LENGTH

structure, with two root nodes, (ii) that features are organized according to Place-Stricture Dependency, and (iii) that the Multiple Linking Principle, and more specifically, Homogeneous Stricture Linking, governs linkings in feature structure. It follows from these three assumptions that rules which produce alterations in specifications for the stricture features should be subject to inalterability with geminates. The Hayes (1986) and Schein and Steriade (1986) theories of inalterability provide no such explanation for why it is predominantly rules affecting these features that are subject to blockage with geminates.

3.2 Lenition and Degemination

As a constraint on wellformed representations, Homogeneous Stricture Linking may either serve to block the application of illformedness-creating rules to geminates, as in the case of inalterability, or it may allow an illformed representation to be derived, but then serve to guarantee that the illformedness be repaired (Paradis 1988a, 1988b). Note that the OCP manifests itself in a similar multitude of ways (see McCarthy 1986; Borowsky 1986, 1987; Yip 1988; Myers 1987, 1988). I suspect that evidence of the repair-motivating role for Homogeneous Stricture Linking with geminates comes from languages which pair up lenition and degemination, as in Finnish (Vainikka 1988) or Old French (Jakobs and Wetzels 1989). In these languages, in just the contexts where a simple segment undergoes sonorantization or spirantization, geminates are simplified to one.

In Finnish, under certain morphological circumstances, a lenition process referred to as 'gradation' weakens a stop which is in the onset of a closed syllable if that stop is preceded by a sonorant (see e.g. Karlsson 1983, Prince 1984, Vainikka 1988). I will argue that the rule should be formulated as follows:


\[
\begin{array}{c}
\text{Syl} \\
| \hspace{1cm} | \\
\text{+son -cont -cons +cons} \implies \text{+son +son -cons +cons}
\end{array}
\]
When this onset stop is preceded by a vowel, or by a nonhomorganic sonorant, we find the following alternations:

(43) \( p/v: \) tapa/tavan 'custom', halpa/halvan 'cheap'
    \( t/d: \) kota/kodan 'Lappish tent'
    \( k/w, k/j, k/\emptyset: \) luku/luwun 'chapter',
    kulke/kuljen 'to go',
    pyrki/pyrin 'to strive'

The segments represented orthographically as \( v, d, j \) and \( w \) are all sonorant continuants, at least in the dialects (\( d \) is a stop in the standard). The exact conditions for the variations in the gradation of \( k \) will not concern us here (see Vainikka 1988, Cathey 1988). Clearly the gradation rule introduces the feature [+sonorant] into the representation of the onset consonant (the stophood of \( d \) in the standard I take to be a secondary effect). I will assume this introduction of [+sonorant] has the automatic result of eliminating any [-sonorant] already present, as shown in (44b):

(44) Sonorant + Stop becomes Sonorant + Sonorant

\[
\begin{array}{ccc}
\text{a. Root} & \text{Root} & \text{c. Root} \\
+/\text{cons} & +\text{cons} & +\text{cons} \\
+\text{son} & -\text{son} & +\text{son} \\
\text{Place} & -\text{cont} & \text{Place} \\
\end{array}
\]

\[
\begin{array}{ccc}
\text{b. Root} & \text{Root} & \text{c. Root} \\
+/\text{cons} & +\text{cons} & +\text{cons} \\
+\text{son} & +\text{son} & +\text{son} \\
\text{Place} & -\text{cont} & \text{Place} \\
\end{array}
\]

\[
\begin{array}{ccc}
\text{Place} & \text{Place} & \text{Place} \\
\end{array}
\]

\[-/+\text{cons} & +\text{cons} & +\text{cons} \\
+\text{son} & +\text{son} & +\text{son} \\
\text{Place} & \text{Place} & \text{Place} \\
\]

\[
\begin{array}{ccc}
\text{e.g.} & \text{l p} & \text{v} \\
\end{array}
\]

The elimination of the specification [-continuant] on the gradated segment, shown in (44c), I assume to be a quasi-automatic effect. Sonorants would normally lack a specification for continuancy.

Let us now settle some of the details of the formulation of the rule above. The gradation rule affects only stops. The sole fricative of Finnish, \( s \), remains unaltered in the gradation environment:

(45) No gradation of \( s: \)

\[
\text{naisel 'woman', naiselta 'from the woman'}
\]

For this reason, the formulation of the rule in
(42) specifies that the onset consonant must be [-continuant]. That gradation is restricted to contexts where a sonorant segment precedes the target stop is shown by examples like those in (46):

(46) No gradation when an obstruent precedes

matka/matkan 'trip'  
piispa/ piispan 'bishop'

The onset stop remains unlenited when another obstruent precedes. There's one final detail which I will leave till later, namely the articulation of the adjacency conditions that a rule with such a structural description presupposes.

Note next that when a homorganic sonorant consonant precedes a stop in the gradation environment, the stop assimilates completely to the sonorant:

(47) Gradation after homorganic sonorant

rampa/ramman 'lame'  
kanta/kannan 'heal'  
valta/vallan 'power'  
parta/parran 'beard'

lagka/lanjan 'thread'

The explanation for this alternation relies on assuming that the gradation rule does indeed apply in these cases, just as we would expect, given the presence of a preceding sonorant. The intermediary representation produced by gradation is then submitted to additional changes, which can be analyzed as repairs of illformednesses in representation that are produced by gradation in these cases. (See Selkirk(1990) for details.)

Finally, we come to the treatment of geminate stops under gradation. In just the same gradation environment as we have examined above, a geminate stop is degeminated:

(48) lappu/lapun 'piece of paper'  
muuttaa/muutan 'move/I move'  
virkkaa/virkan 'utter/I utter'
These alternations between geminate and simple stop can be ascribed to the operation of the same rule of gradation given in (42), if we assume that Homogeneous Stricture Linking is at play here, and motivates repairs to any ill-formed representations introduced by gradation. Gradation applies to the second, onset, half of the geminate, eliminating the identity between the heads of the doubly linked dependent [-continuant], as shown in (49b), and thereby creating a multiple linking that is ill-formed according to Homogeneous Stricture Linking:

(49) Gradation with Geminates, and Degemination

\[
\begin{array}{ll}
\text{a. Root Root} & \text{b. *Root Root} \\
+\text{cons} & +\text{cons} \\
-\text{son} & -\text{son} \\
\vee & \vee \\
-\text{cont} & -\text{cont} \\
\mid & \mid \\
\text{Place} & \text{Place} \\
\end{array}
\]

\[
\begin{array}{ll}
\text{c. Root Root} & \text{d. Root Ø} \\
+\text{cons} & +\text{cons} \\
-\text{son} & -\text{son} \\
\mid & \mid \\
-\text{cont} & -\text{cont} \\
\mid & \mid \\
\text{Place} & \text{Place} \\
\end{array}
\]

I suggest that this ill-formed representation is 'repaired' by eliminating the double-linking, specifically, through eliminating the link to the onset consonant, as shown in (49c). This results automatically in the loss of a Place specification for the onset consonant. And this loss of a Place specification has as a consequence the deletion of the Root itself, as shown in (49d), for a segment cannot be realized without a Place specification. In other words, the geminate stop is reduced to a single stop as a consequence of the application of gradation to the geminate. (For further discussion of the application of gradation to geminates, see Selkirk 1990.)

So here we have a coherent story for all the phenomena which go under the name gradation in Finnish. Of course the account crucially relies on theoretical proposals for which independent independent motivation is required: Homogeneous Stricture Linking (and more generally the Multiple
Linking Constraint), Place-Stricture Dependency, and the two-root theory of length. This paper is concerned only with providing general motivation for the two-root theory of length. As for the other theoretical proposals, here I can only assert their well-foundedness, and draw the consequences for the theory of geminate inalterability. Earlier theories of geminate inalterability (Steriade 1982, Schein and Steriade 1986 and Hayes 1986) have absolutely nothing to say about the pairing of lenition and degemination that is to be found in Finnish and other languages. Indeed, they predict unequivocally that gradation should be blocked from applying to geminates in Finnish. The existence of degemination alongside gradation, in exactly the same prosodic and morphological contexts, must simply be construed as accidental. In order to capture the gradation/degemination relation, it seems that theories like that of Hayes and Schein and Steriade will have to be abandoned, and that a theory tracing the behavior of geminates to constraints on wellformed representations, such as has been proposed here, should be adopted.

I have not shown here that all the cases of geminate inalterability discussed in the literature submit to the reanalysis offered here. And indeed I could not do so. The Schein and Steriade article presents certain recalcitrant cases. My bet is that these will end up falling under the purview of yet other conditions on representational wellformedness. In any case, the approach outlined here goes a great deal further than both the Hayes and Schein and Steriade approaches in predicting the behavior of rules with respect to multiply-linked structures, including geminates, and shows the value of giving general wellformedness conditions on representation a central role in phonological description.

TWO-ROOT LENGTH AND SYLLABLE/MORA STRUCTURE

4. Compensatory Lengthening

It now seems securely established that the phenomenon of compensatory lengthening depends on a moraic representation of quantity, not a segmental representation, as with Ingria 1980 and Leben 1980. Hock 1986 and Hayes 1989 have laid out the basic arguments for this. Hock, McCarthy-Prince and Hayes articulate the moraic theory of compensatory...
lengthening assuming a one-root theory of length. But this is not necessary. I want to show here that a two-root theory of length allows just the same insights into the moraic character of compensatory lengthening.

The basic tenet of the moraic theory of compensatory lengthening is that only segments which have moraic status in prosodic structure are compensated for when lost. Deletion of a segment will leave behind the mora it was associated with. Compensatory lengthening is viewed as a way of giving segmental anchoring to the mora left floating by the deletion. For simplicity's sake let's look at the most typical sort of compensatory lengthening case, rather than the more exotic ones discussed by Hock and Hayes. The deletion of a syllable-final moraic consonant sets the stage, as shown in (50).

(50) Syl
   | m m
   | RC RV RC
   ===>
   | m m
   | RC RV
Deletion

According to one-root theory, the vocalic root node then simply associates to the floating mora, creating a long bimoraic vowel, as shown in (51).

(51) A One-Root Approach

Syl
   | m m
   | RC RV

Spreading of the Root Node

But there is another possible scenario. The floating mora could be supplied segmental content through the epenthesis of a root node, as shown in (52). The remaining features for the epenthesized root would be obtained by spreading from a neighbor. I have illustrated this approach with vocalic root node epenthesis. There are also instances of compensatory lengthening where consonantal root node epenthesis would be in order.
A TWO-ROOT THEORY OF LENGTH

(52) A Two-Root Approach: Mora-motivated Root Epenthesis

Epenthesis

Spreading of Features

Root epenthesis, then, provides an account of moraic compensatory lengthening that is consistent with a two-root theory of length.

A plausible case can be made that all epenthesis is root epenthesis, and exists to satisfy prosodic structure conditions (see Itô 1986, 1989). Epenthesis that is motivated specifically by mora structure has ample independent motivation in grammar aside from its utility in compensatory lengthening. For example, it is likely that Shona (Myers 1987), Lardil (Wilkinson 1986) and Campa (Levin 1985, Itô 1989) all require a word to be minimally bimoraic in size. (See McCarthy and Prince 1986 on bimoraic word templates.) When the output of the morphology is a lone monomoraic stem, epenthesis supplies the extra vowel that will allow the bimoraic word template to be satisfied.

We see, then, that understanding compensatory lengthening in moraic terms in no way implies a one-root theory of length. Epenthesis and the two-root theory of length it presupposes are equally viable as an account of moraic compensatory lengthening.

5. The Distribution of Geminate Consonants

According to the one-root theory of length put forth by McCarthy-Prince 1986, 1988, 1990 and Hayes 1989, long segments are lexically represented as a single root node preassociated to a mora. The double-linking that is the hallmark of a long segment is produced as part of the syllabification process, which associates the already-moraified
root node to some other syllabic position. Let us call this gemination-by-syllabification. It is illustrated for geminate consonants in (53):

(53) The One-Root Theory of Geminate Consonants (McCarthy-Prince, Hayes)

Lexical Rep: m Derived Rep: Syl Syl

\[ \text{RC} \quad \text{Syl} \]

There are two fundamental claims made with this analysis. The first is that a geminate consonant counts as a mora in the syllable that it closes. This claim will be evaluated in the last section. The second is the claim that geminate consonants are located only where general principles allow for the presence of moras. A geminate may be heterosyllabic, as in (53), where its lexical mora occupies a position in the latter part of the first syllable. Conceivably, a geminate consonant could also be entirely contained within a rime. But it is categorically ruled out that a geminate could be contained in the onset of a syllable. Given the gemination-by-syllabification theory, for there to be a double association of a single root consonant to two positions in the onset, one of those positions would have to be the lexically associated mora. But this is an impossible syllable/mora structure.

It does seem to be quite generally the case that geminates fail to appear in onsets. But this nonetheless does not lead us to favor the one-root theory just sketched over the two root theory that has been defended up to now. Suppose the lexical representation of geminate consonants consisted of two consonantal roots, doubly linked for the relevant features, as in (6) or (28). Is there a principled means of ruling out the presence of geminates within the onset of a syllable? Certainly, other sequences of consonant roots are permitted within the onset in some languages. Yet we know that there are often severe cooccurrence restrictions on those sequences. The consonants of onset sequences are typically required to be different in kind. Constraints on the minimal sonority difference (Selkirk 1984, Steriade 1982) required between adjacent consonants are more severe within onsets than within codas. Sequences
of stop-stop, fricative-fricative, etc. are typically avoided. Therefore geminate consonants, which on two-root theory consist of a sequence of identical root/stricture feature specifications, will be excluded by standard minimal sonority difference requirements. If the banning of geminates from onsets is indeed to be attributed to minimal sonority difference considerations, then it is predicted that a language with geminates which does allow stop-stop, nasal-nasal or other sequences in the onset will also allow geminates to appear there. Further research will allow us to see whether this prediction, one which distinguishes between the moraic one-root theory of length and the two-root theory, is borne out.

6. Geminates and Stress

The version of one-root theory that is put forth by McCarthy-Prince and Hayes holds that geminate consonants are universally represented as moraic in lexical representation, as shown in (53) above. This means that syllables with a short vowel that are closed by a geminate consonant are predicted to be universally bimoraic: one mora from the vowel and one from the geminate consonant. Nongeminate consonants which close short vowel syllables are not necessarily moraic. They will not be moraic unless a language-particular rule assigns mora status to them. Such a rule will be called Weight-by-Position, following Hayes (1989). Its effects are illustrated in (54).

(54) Weight-by-Position (language-particular)

```
   Syl   Syl
  /|\   /|\  ====>  /|\  /|\  \\
 m   m   m   m
   RC  RV  RCa  RC  RV  RCa
```

(RCa may designate particular consonant types, e.g. sonorant consonants, as in Kwakiutl (Bach 1975), or Danish (Basbøll 1988).)

If a consonant is not assigned morahood by this rule, it could simply be syllabified as a nonmoraic coda by the Coda Rule, as shown in (55).
(55) Coda Rule (the default case)

\[
\begin{array}{c|c|c|c}
\text{Syl} & \text{m} & \text{Syl} \\
\hline
\text{RC} & \text{RV} & \text{RC} \\
\text{RC} & \text{RV} & \text{RC}
\end{array}
\]

So short vowel syllables that are closed by a nongeminate consonant come in two varieties, depending on the language: monomoraic or bimoraic. As for syllables with long vowels, they are necessarily bimoraic in one-root theory, just as short vowelled open syllables are monomoraic. These assumptions of one-root theory about the moraic quantity of the various syllable types are summed up in the table in (56).

(56) Moraic Quantity of Syllable Types--One-Root Theory

Universally bimoraic: \(CV_iV_i\), \(CVC_i.C_i\)

Monomoraic or bimoraic: \(CVC_i.C_j\)

(depending on whether a language has Weight-by-Position)

Universally monomoraic: \(CV\)

There are two interrelated predictions about the behavior of geminate consonants with respect to stress that are made by this theory. The first is that there should not exist languages with geminate consonants which treat only long vowel syllables as bimoraic. A syllable closed by a geminate is necessarily bimoraic and thus must pattern with a long vowel syllable, also necessarily bimoraic. The second is that long vowel syllables and short vowel syllables closed by a geminate consonant can form a natural class on their own and behave differently from short vowel syllables closed by a nongeminate consonant. This would be the case in a language which did not assign Weight-by-Position.

The first prediction crucially differentiates the one-root moraic theory of length from two-root theory. In two-root theory no segment is lexically moraic, at least in the normal case. A language will have general rules for assigning morahood to vowels and consonants. I presume that each vowel root is normally assigned moraic status, though
there are plausibly cases where a sequence of two vocalic roots is monomoraic, as with short diphthongs, discussed above. Morahood is certainly not necessarily assigned to consonants. For consonant roots to be moraic, whether the first half of a geminate or not, Weight-by-Position, rule (54), must apply. If Weight-by-Position doesn't apply, then the only bimoraic syllables in the language, if there were any at all, would be those with long vowels. In this way, then, two-root theory predicts the existence of a class of languages whose existence is denied by the one-root moraic theory of length.

Evidence relevant to deciding between these theories will come inter alia from the word stress systems of the world, in particular those that are transparently mora-counting. Mora-counting stress systems are those in which bimoraic heavy syllables function on a par with pairs of monomoraic light syllables. These latter will show an alternating pattern. What we need to look at then are languages which (i) have geminates, (ii) have long vowels, (iii) have a mora-counting stress system. Possible languages of this sort are the different varieties of Eskimo or Uto-Aztecan languages like Southern Paiute, Tubatulabal or Cahuilla. They have alternating patterns of stress and probably treat only long vowels as heavy. But the status of geminates in these languages needs to be clarified before they stand as counterexamples to the one-root moraic theory of length. It is languages of this sort--call them 'C-languages' ('C' for 'crucial')--that will provide evidence distinguishing between the lexically moraic one root theory of length and the two root theory of length.

The second prediction made by one-root theory is that a language may treat long vowel syllables and short vowel syllables closed with a geminate as a natural (bimoraic) class, distinguished from (monomoraic) short vowel syllables closed with a nongeminate consonant. But this prediction does not distinguish between the two theories, as John McCarthy has pointed out to me. Two-root theory could in principle derive this pair of natural classes as well. In two-root theory the morahood of consonants is always derived by the rule of Weight-by-Position. Suppose that on a language-particular basis Weight-by-Position were to be constrained so as to apply only to geminate consonants. This
could perhaps be accomplished by some analogue of the Coda Condition (Ito 1986, 1989), which guarantees that only the first half of geminates (partial or total) may be syllabified as a coda in some languages. The idea is that Weight-by-Position could be so constrained, but applications of the Coda Rule (52) not. This would derive the bimoraicity of short vowel syllables closed by geminates, alongside the monomoraicity of other short vowel syllable types. Hence the natural classes sanctioned as well by one-root theory. Of course if Weight-by-Position were not so constrained, then short vowel syllables closed by any consonant of the same type--whether geminate or simple--would be treated in the same fashion. Both would either be bimoraic, or monomoraic, depending on whether Weight-by-Position applied.

The predictions about natural classes made by two-root theory are summed up in (57).

(57) Moraic Quantity of Syllable Types—Two-Root Theory

Strong universal tendency towards bimoraicity: CVV

Monomoraic or bimoraic: CVC_i.C_i, CVC_i.C_j

(depends on whether a language has Weight-by-Position, and whether W-by-P is governed by something like the Coda Constraint)

Universally monomoraic: CV

The two-root theory thus allows for a flexibility in the quantitative status of geminate consonants (and vowels as well). It is the C-languages that will allow us to decide whether this flexibility is required.

CLOSING REMARKS

I undertook this investigation in the hopes of understanding more clearly the nature of the interface between feature structure and prosodic structure in phonological representation. In particular, I wanted to see whether the so-called skeletal tier—the one composed of C's and V's or X's—had any place in the representation. I think this paper provides support for a theory in which there is no skeletal tier mediating between feature structure and prosodic structure, as illustrated in
Since the purpose of this paper has been to investigate the theory of length from the point of view of phonology, by looking at what operations on phonological representation tell us about the representation of long consonants and vowels, issues concerning templatic morphology have not been dealt with. Yet the two-root theory of length has obvious implications for the theory of prosodic morphology. Let me name just two in closing. First, given that two-root theory in effect encodes length in the 'melody', namely in the root nodes, so-called transfer effects in reduplication (McCarthy & Prince 1988) probably fall out without mention. (Thanks to Armin Mester for pointing this out to me.) Second, the multiple linking of root nodes to the skeleton, assumed, for example, for Semitic templatic morphology, can not be an enduring property of the phonological representation that is derived from the morphological mapping of melody to skeleton. Rather it must simply be an ephemeral step in the morphological mapping procedure, one which is followed by a 'tier conflation' producing in all cases representations of the sort that have been argued for here, wherein each root has a single association to the syllable/mora structure of the skeleton.

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