Diphthongisation and coindexing*

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1 Introduction

The tree model of segment structure proposed by Clements (1985)[1] is an important innovation in phonological theory, making possible a number of interesting predictions about the form of phonological rules, locality of rule application, and the organisation of the feature system. Clements' proposal has given rise to an expanding literature, including Sagey (1986), Schein & Steriade (1986), McCarthy (1988), Archangeli & Pulleyblank (forthcoming) and other work.

In this article, I argue that the tree model as it stands faces a serious shortcoming: it fails to provide an adequate account of diphthongisation rules, here defined as rules that convert a segment (vowel or consonant) into a heterogeneous sequence. To solve the problem, I propose a revised tree model, which for clarity uses coindexation rather than association lines to indicate temporal association.

The article is organised as follows. §§2–7 lay out the diphthongisation problem, sketch a solution, and show how it works. In §8 I discuss several more complex diphthongisation rules, invoking the theory of particle phonology (Schane 1984a). §9 addresses further issues raised by the formal proposal, and the final section discusses the alternative account of diphthongisation in Selkirk (1988).

2 Theoretical background

I assume here some version of 'CV phonology'; i.e. the theory propounded in McCarthy (1979) and Clements & Keyser (1983); or its formal descendants: X theory (Levin 1985; Lowenstamm & Kaye 1986) and moraic theory (Hyman 1985; McCarthy & Prince forthcoming; Hayes 1989). The choice of prosodic theory will not be crucial here. What will be important is the claim, common to all three theories, that long segments are represented as doubly linked. Using CV theory for concreteness, this is illustrated under (1):

(1) a. /pp/ = C   C 　　　　b. /aː/ = V   V
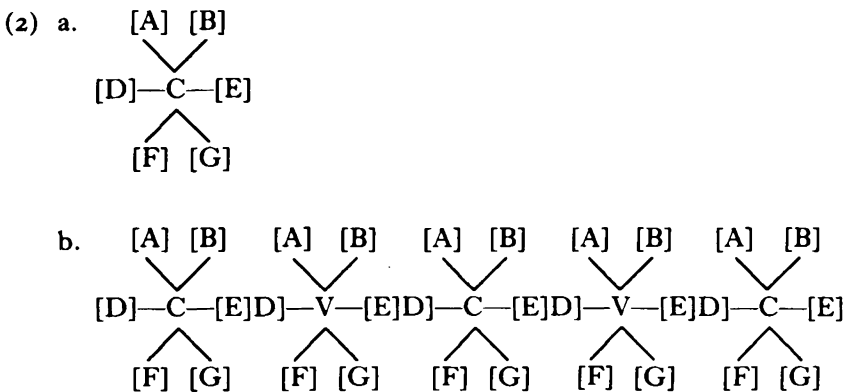　　　　　　　　　　 ＼／　　　　　　　　　　　　　 ＼／
　　　　　　　　　　　p　　　　　　　　　　　　　　　a
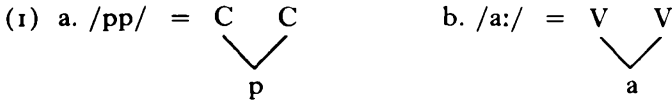
Doubly-linked representation of length is enforced by the Obligatory Contour Principle (McCarthy 1986).

A great deal of evidence supports doubly-linked representations. For example, they largely solve the paradoxes of length discussed in Kenstowicz (1970): long segments act as units for rules affecting segment quality, but as sequences for prosodic rules. Doubly-linked representations are supported by psycholinguistic evidence: in language games (Odden 1981; Clements 1986a) and speech errors (Stemberger 1984), segments can 'move', taking on the length inherent to the location they move to. Further, the structures of (1) sometimes contrast with sequences of two identical segments created by morpheme concatenation, and can exhibit phonologically different behaviour: doubly-linked long segments cannot be split by epenthesis, and obey inalterability constraints (Steriade 1982; Schein & Steriade 1986; Hayes 1986). A more thorough review of this evidence appears in Hayes (1986: 322–330).

I also assume some version of 'radical autosegmentalism'; i.e. a theory that posits enough autosegmental tiers to express all assimilation as spreading. This idea is also well supported. In particular, the classical arguments that tone is on a separate tier (Goldsmith 1976), such as stability under deletion, can be replicated with other phonological features (e.g. nasality, vowel features, laryngeal features and place features). Moreover, the arguments for doubly-linked long segments in CV theory can be replicated for certain segment sequences that share only a subset of their feature values (Steriade 1982; Itô 1986).

Probably the simplest version of radical autosegmentalism would be one in which every feature occupies a separate tier and is linked directly to the prosodic tier (CV or otherwise). In such a theory, a single segment would appear as in (2a), and a sequence of segments would be depicted (awkwardly, since the representation has three dimensions) as in (2b):

(2) a.　　　 [A] [B]
　　　　　　　 ＼／
　　　　　 [D]—C—[E]
　　　　　　　 ／＼
　　　　　　 [F] [G]

b.　　 [A] [B]　　[A] [B]　　[A] [B]　　[A] [B]　　[A] [B]
　　　　 ＼／　　　　 ＼／　　　　 ＼／　　　　 ＼／　　　　 ＼／
　　 [D]—C—[E]D]—V—[E]D]—C—[E]D]—V—[E]D]—C—[E]
　　　　 ／＼　　　　 ／＼　　　　 ／＼　　　　 ／＼　　　　 ／＼
　　　 [F] [G]　　[F] [G]　　[F] [G]　　[F] [G]　　[F] [G]

I will refer to this theory as the BOTTLEBRUSH THEORY, since the CV tier in it resembles the spine of a bottlebrush, with features branching off in rows.

While the Bottlebrush Theory enables all features to behave auto-segmentally, it suffers from a serious defect: in phonological rules, features form characteristic groupings. For instance, the features describing place of articulation often assimilate collectively (cf. the common use of the notation '[αplace]'). Similarly, the laryngeal features can act together in assimilation and other rules; as can the place + manner features, the supralaryngeal features, and so on. Nothing in the Bottle-brush Theory (or in standard *SPE* phonology) predicts that features should be grouped this way in rules.

The preceding point is made by Clements (1985), who proposes a theory of feature grouping which has since been widely adopted. The basic idea is that feature grouping forms part of the inherent structure of segments. To account for the subset relations in feature grouping, Clements suggests that groupings are hierarchical. For example, the features for the tongue body ([high], [back], [low]) form a subset of the features for place of articulation, which form a subset of the features for supralaryngeal configuration, and so on. Clements expresses the hierarchical structure of the feature sets using tree notation. One version of the feature tree, which includes modifications suggested by Sagey (1986) and others, is shown in (3):

(3)
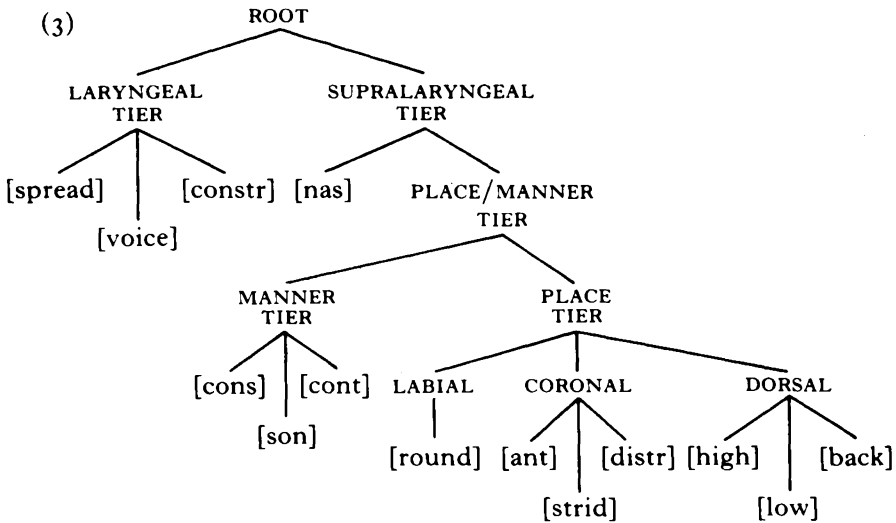
Within the tree, every constituent (terminal nodes included) defines a separate tier, accessible to phonological rules for spreading and other operations.

No consensus exists concerning the exact structure of the tree, par-

ticularly at higher levels; see Sagey (1986), Archangeli & Pulleyblank (forthcoming) and McCarthy (1988) for particular proposals. The differences between these theories will not be crucial in what follows, and I will assume the structure of (3) for concreteness.

Feature trees depict only subset relations among feature sets, not linear ordering: the order in which sister nodes appear on the page is purely conventional. A full phonological representation can be visualised with three dimensions, consisting of a stack of feature trees, associated (not necessarily one-to-one) with prosodic positions:

(4) a. /aː/ = σ   b. /appa/ = σ   σ
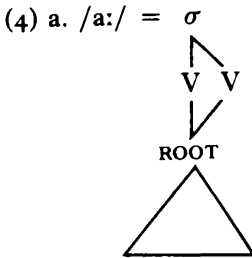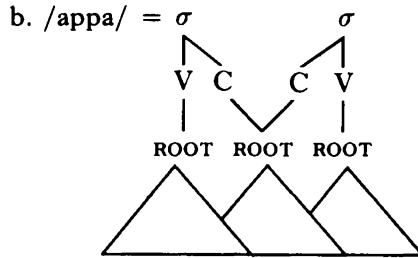
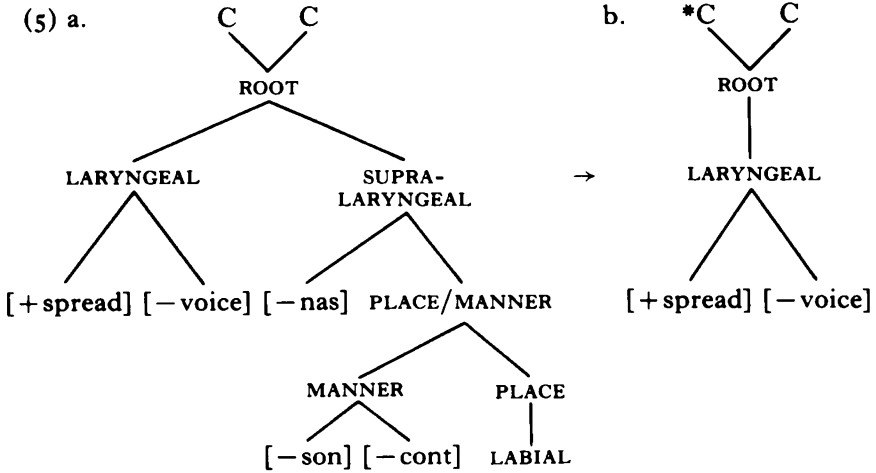(Feature tree for /a/)   (Feature trees for /a, p, a/)

To make predictions about the characteristic groupings of features involved in rules, the theory posits that rules are constrained to manipulate only constituents, which may consist of a single feature as the degenerate case. It remains to be seen whether the constituency hypothesis can be maintained as a universal, or is only a statement of markedness. In any event, the structured trees are preferable to a theory (e.g. the Bottlebrush Theory) that says nothing at all about characteristic feature groupings.

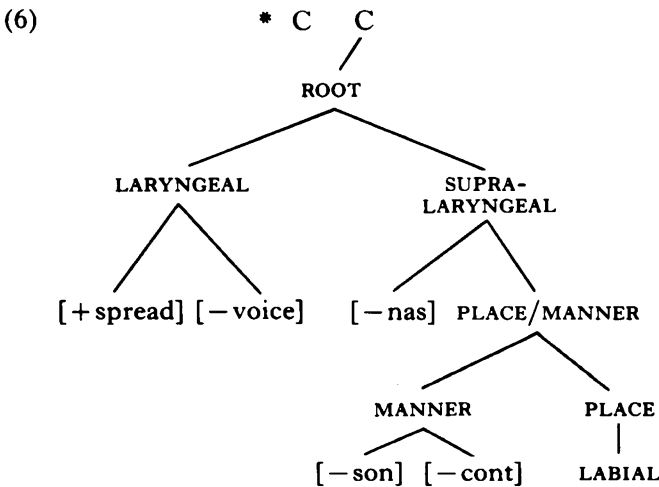## 3 The diphthongisation paradox

Consider now the analysis of diphthongisation within a Clements-cum-CV model of segment structure. We will encounter here a contradiction, which I will call the 'diphthongisation paradox'. The paradox arises from the conflicting claims of tree theory and the prosodic representation of length.

As an example I will discuss an instance of consonant diphthongisation, the Preaspiration rule of Icelandic, first analysed autosegmentally by Thráinsson (1978). This rule converts the geminate voiceless aspirated stops /pp tt kk/ to phonetic [hp ht hk]. Articulatorily, this is a simple process, in that the aspirated voiceless stops and /h/ are both [+spread glottis]. Because of this, the preaspirated stops can be derived simply by removing the supraglottal articulation from the first half of the geminate. This is the core of Thráinssson's analysis, and it is carried over into Clements' (1985) account.

However, the formal expression of Preaspiration in Clements' theory is not straightforward. In particular, consider the representation for geminate /pp/, in (5a). Since long segments are doubly linked, there is only one /p/ autosegment present on the Supralaryngeal tier. Deleting this autosegment, we obtain *[hh], as in (5b), and not the correct form [hp]:
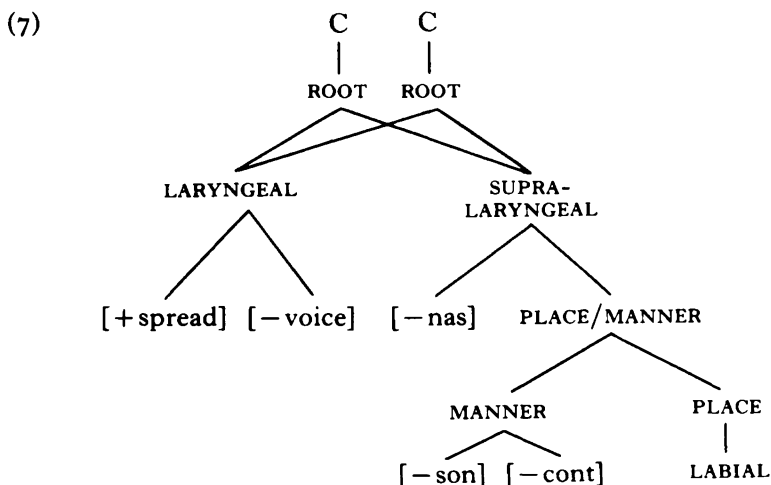
(5) a.

```
        C     C
         \   /
         ROOT
         /    \
   LARYNGEAL   SUPRA-
               LARYNGEAL
   /      \    /       \
[+spread] [−voice] [−nas] PLACE/MANNER
                          /         \
                     MANNER          PLACE
                     /    \            |
                 [−son] [−cont]      LABIAL
```

→

b.

```
        *C     C
          \   /
          ROOT
           |
        LARYNGEAL
         /      \
   [+spread]  [−voice]
```

More generally, the representation provides no way to delink the supralaryngeal specifications of /pp/ only from the first half of the geminate: the only node that is doubly linked is the Root node; and if we remove its first link, we again obtain the wrong result, namely an empty C position followed by a single [p]:

(6)

```
      *  C     C
             /
          ROOT
          /      \
   LARYNGEAL    SUPRA-
                LARYNGEAL
    /      \    /        \
[+spread] [−voice] [−nas] PLACE/MANNER
                          /          \
                     MANNER           PLACE
                     /    \             |
                 [−son]  [−cont]      LABIAL
```
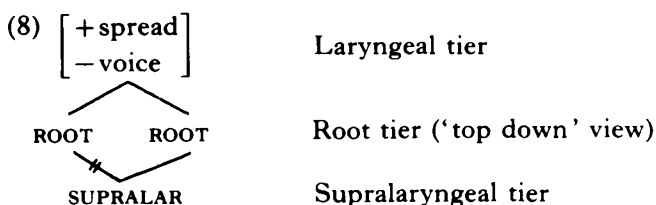
The nature of the difficulty should be clear: Icelandic Preaspiration is a diphthongisation of the supralaryngeal features, but not of the laryngeal features. If both supralaryngeal and laryngeal features are linked to the prosodic tier through a single Root node, then Preaspiration cannot be expressed as a unitary process.

It is instructive to examine Clements' (1985) approach to the problem. His analysis supposes that Icelandic geminates have a different structure from long segments in other languages: they have two Root nodes, each with its own prosodic position. Double linking is found further down the tree, at the Laryngeal and Supralaryngeal tiers:

(7)

C   C
| |
ROOT   ROOT

LARYNGEAL   SUPRA-
                      LARYNGEAL

[+spread] [−voice]   [−nas]   PLACE/MANNER

                      MANNER   PLACE
                                            |
                    [−son] [−cont]   LABIAL

Given this, it is straightforward to express diphthongisation as follows:

(8) $\begin{bmatrix} +\text{spread} \\ -\text{voice} \end{bmatrix}$ Laryngeal tier

ROOT   ROOT   Root tier ('top down' view)

SUPRALAR   Supralaryngeal tier

This solution seems flawed, since it contradicts the basic principle of prosodic theory that long segments are doubly-linked single units. Many of the predictions of the theory depend on this principle, and they would be eliminated if the structure of (7) is allowed as an alternative. Moreover, nothing in Icelandic phonology independently justifies this structure; to the contrary, there is good reason to believe that Icelandic geminates do have the normal doubly-linked structure of (5a): many of them occur morpheme-internally or are derived by a rule of lengthening (Thráinsson 1978: 6, 29–32). Cross-linguistically, it is in just these contexts that doubly-linked geminates are normally found.

The diphthongisation paradox does not concern only Icelandic; it will arise whenever a feature or node undergoing diphthongisation is embedded in a doubly-linked feature tree.

4 Steriade's proposal

The diphthongisation paradox has been discussed earlier by Steriade (1987b). Steriade studied diphthongisation for three major class nodes: (a) the laryngeal features, as in Southern Paiute, where in certain contexts /mm/ is realised as [mm̥] and /aː/ as [aḁ]; (b) nasality, as in Japanese, where /bb dd/ can be realised as [mb nd]; (c) place features, as in Icelandic Preaspiration.[2] Steriade notes the same paradox: if Laryngeal, Nasal and Place are nodes in the feature tree, then these rules cannot be expressed as unitary operations.

Steriade's solution is to eliminate the Root node from phonological representations. Instead, the Laryngeal, Nasal and Place nodes form separate trees, each linked directly to the prosodic tier:

(9)

$a\ a' = $ Place tier
$b\ b' = $ Laryngeal tier
$c\ c' = $ Nasal tier
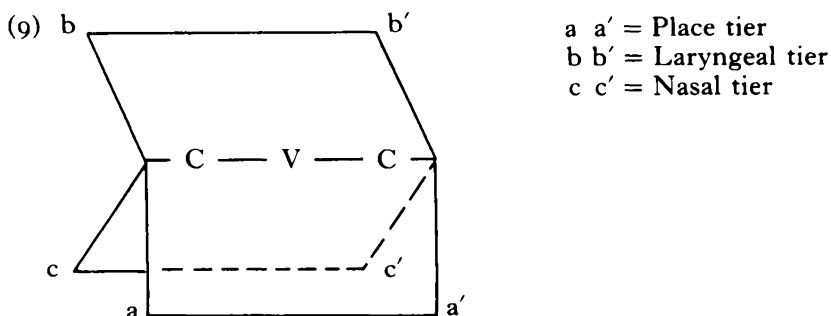
Each tier, being independently linked, can undergo diphthongisation separately. For example, Icelandic Preaspiration can be expressed as follows:

(10)

Place tier

Prosodic tier

Laryngeal tier
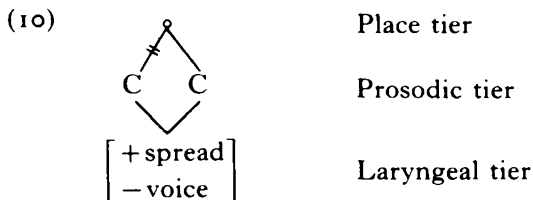
The absence of a Root node seems like an obvious defect in the theory: for example, how can rules of total assimilation be expressed? Steriade notes, however, that in Barra Gaelic (Clements 1986b), the rule that fills in the surface features of epenthetic vowels must take the form 'Spread rightward on all tiers', since for some derivations the source of spreading can lie in a different segment for different features. If 'Spread α' rules of

this sort are necessary in any event, they can be invoked to carry out total assimilation, eliminating the need for a Root node.
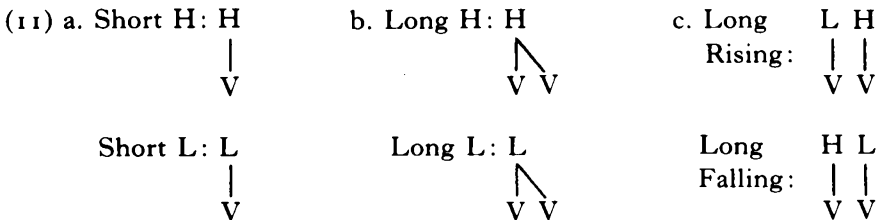
I believe that Steriade has pointed out the right direction for a solution to the diphthongisation paradox. However, her theory does not go far enough, because diphthongisation is not limited to the major class nodes which Steriade links directly to the prosodic tier. Many diphthongisation rules affect just a single feature, deeply embedded within the tree. Such is true, for instance, of the Old French diphthongisation [eː oː] → [ei ou] (Berschin *et al.* 1978), which affected only [high]. It also holds true of the manner diphthongisation of Central Swedish (Elert 1981: 156), whereby the second part of a long high vowel is converted to the homorganic voiced fricative: /iː yː ʉː uː/ → [ijˆ yɥˆ ʉβ uβ]. Numerous other examples appear below.

If diphthongisation in general is to be treated under Steriade's approach, we must split the tree further, associating most of the feature inventory directly to the prosodic tier. Once this is done, we have lost what we wanted the tree to do for us in the first place; that is, we are back to the Bottlebrush Theory. Thus it appears that Steriade's account is not a fully adequate answer to the diphthongisation paradox.

5 The problem of 'vowel-feature-bearing' units

We can bring the diphthongisation paradox into closer focus by considering the typology of vowel diphthongisation and the notion of feature-bearing unit (Clements 1980).

Note first the following precedent from tonal phonology: in many languages (e.g. Ancient Greek, Navajo and Makua), falling and rising tones are allowed only on long vowels or diphthongs. This natural restriction can be expressed straightforwardly in a prosodic theory: in such languages the feature-bearing units for tone are V positions on the CV tier (or their equivalent in other theories). If the language restricts tone-bearing units to just one tonal association, then the restriction of contour tones to long nuclei falls out in a natural way:

(11) a. Short H: H   b. Long H: H   c. Long   L H
           | ⋀   Rising: | |
           V   V V   V V

    Short L: L   Long L: L   Long   H L
              | ⋀   Falling: | |
             V   V V   V V

This argument is a familiar one. Slightly less familiar is the fact that the same argument can be applied to vowel features as well. If one examines the typology of diphthongisation rules, the most striking tendency (noted in Donegan 1978) is that only long vowels undergo diphthongisation. The following chart gives an overview:

(12) *Diphthongisation rules*

Middle English	[iː uː] → [ei ou]	(beginning of Great Vowel Shift)
Old High German	[eː oː] → [ea oa] → [ia ua] → [ie uo]	(Penzl 1969)
New High German	[iː uː] → [ai au]	(Chambers & Wilkie 1970)
Icelandic	[eː oː øː] → [eɛ ɔɔ øœ]	(Garnes 1976)
Faroese	[uː oː iː yː] → [yu ou ui ui]	(Rischel 1968)
Central Swedish	[iː yː ʉ uː] → [ij^ yɥ^ ʉβ uβ]	(Elert 1981)
Scanian Swedish	long vowels (see below; §8.3)	(Bruce 1970)
Mälaren Region Swedish	[Vː] → [Və]	(Elert 1981)
Western Romance	[eː oː] → [ie uo][3]	(Otero 1988)
Apulian	long vowels[3]	(Stehl 1980)
Old French	[eː oː] → [ei ou][3]	(Berschin *et al.* 1978)
Quebec French	Vː in stressed syllables (see below; §8.4)	(Dumas 1981)
Slovak	[eː oː æː] → [ie uo ia] in derived environments	(Kenstowicz & Rubach 1987)
Czech Common Language	[eː oː] → [ei ou]	(Kučera 1961)
Old Prussian	[eː oː] → [ei ou]	(Schmalstieg 1964)
Eastern Finnish	[eː øː oː æː aː] → [ie yø uo eæ oa]	(Kiparsky 1968)
Southern Lappish	[iː yː uː eː oː] → [ie yø uo eæ oa]	(McCawley 1973)
Cakchiquel (Santa Maria de Jesus dialect)	[eː oː] → [ie uo]	(Campbell 1971)

The point is that vowel features resemble tone features in usually obeying a one-per-V-position constraint. The inference to be made is that the 'vowel-feature-bearing units', just like the tone-bearing units, are V positions on the CV tier. Again, this contradicts the evidence that vowel features are deeply embedded within the feature tree.

It is true that short diphthongs exist. But their frequency should not be overestimated. For example, some cases in which a vocoid sequence is claimed to be a short diphthong might also be analysed as involving a glide in onset position, followed by a short vowel. This appears to be true, for instance, of Kaye's (1981) account of 'short diphthongs' in Vata. Incontrovertible cases of short diphthongs are found in Chevak Yupik Eskimo (Woodbury 1981), Icelandic (Anderson 1984) and Faroese (Rischel 1968). However, none of these is the result of diphthongisation; rather they involve an originally long diphthong, compressed in a closed syllable by the loss of a V position. I know of no clear evidence to suggest that true diphthongs may arise spontaneously within short nuclei.

6 Resolving the diphthongisation paradox

I believe the diphthongisation paradox is rooted in an ambiguity of formalism. Phonologists characteristically encode their representations graphically, as lines on a page. In principle, this is a good idea, since it usually makes the representations easier to visualise and manipulate. But it is important to have in mind a clear notion of what graphic formalisms are intended to stand for.

A line in a phonological representation can normally mean one of two things. In autosegmental theory a line indicates, roughly, simultaneity (see

Sagey 1988 and Hammond 1988 for more refined interpretations). Thus (13a) indicates that H tone is pronounced together with the vowel /a/. Lines on the page have an additional meaning, however, in that they can indicate category membership. Thus in (13b), the lines indicate that the segments /tap/ belong to a single syllable:

(13) a. Association H   b. Category   σ
     Lines: | Membership   /\\ = [tap]$_\sigma$
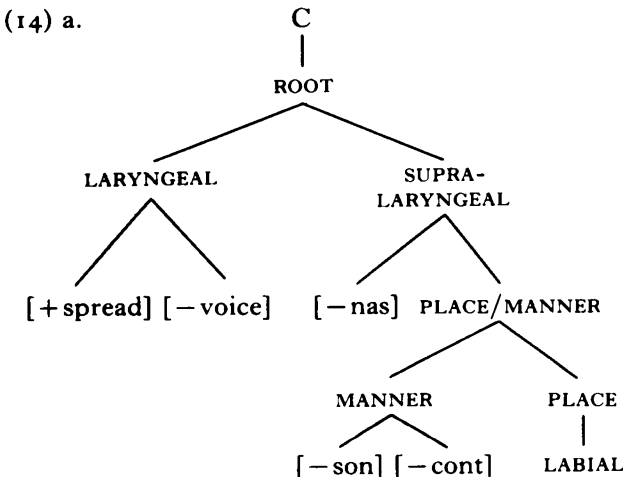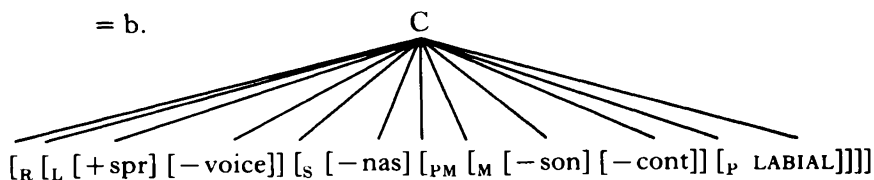   a   Lines: t a p
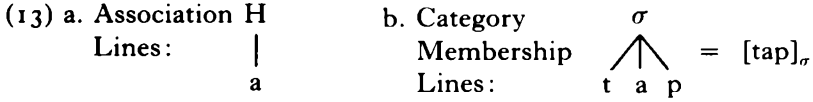
What are the lines in a feature tree? Here, the two functions are conflated: the lines depict a hierarchy of category membership, but at the same time they serve to link all nodes, directly or indirectly, to the prosodic tier. It is this ambiguity, I believe, that leads to the diphthongisation paradox. Once we separate the two functions, the paradox disappears.

6.1 A revised theory

My proposal, then, is as follows: lines in a feature tree are not association lines, but indicate only category membership. All true association lines mediate directly between the tiers of the feature tree and the prosodic tier. In other words, Clements' theory is correct in so far as it establishes a logical grouping of the features, but the Bottlebrush Theory is correct in requiring that linkage be directly to the prosodic tier. To visualise the proposal, the reader should imagine a feature tree on which lines have been superimposed to link every feature and class node directly to the prosodic tier.

As I will show below, such a proposal suffices to solve the diphthongisation paradox. But the spaghetti-like representations it involves are obviously impractical. To get around the problem, I will use for the moment representations like (14b), which translates the feature tree for /p/ in (14a):

(14) a.

```
                    C
                    |
                  ROOT
                 /      \
         LARYNGEAL      SUPRA-
            /\          LARYNGEAL
           /  \           /    \
   [+spread] [-voice]  [-nas]  PLACE/MANNER
                                   /    \
                                  /      \
                              MANNER     PLACE
                               /\          |
                              /  \         |
                        [-son] [-cont]   LABIAL
```

= b.   C

$[_R [_L [+spr] [-voice]] [_S [-nas] [_{PM} [_M [-son] [-cont]] [_P \text{LABIAL}]]]]$

In the revised representation, grouping information is expressed using labelled brackets, and each feature, as well as each class node, is linked by an association line directly to the C position. For non-terminal nodes, association is indicated with a line reaching the left labelled bracket.

This reformalisation clearly separates the functions of feature grouping and temporal association. However, it has what may initially seem to be a serious defect, in that it misses a generalisation that the original formalisation captures, namely: if node N is linked to a set S of CV positions, then each node dominated by N is also linked to all positions in S. For example, a Labial node must be linked to all of the CV positions to which its dominating Place node is linked, a Place node must be linked to all of the CV positions to which its dominating Place/Manner node is linked, and so on. In other words, linkages are always inherited down the tree.[4] With the original tree theory, downward inheritance is an automatic consequence of the formalism, but this is not so in the theory proposed here.

However, as I will argue below, the advantage actually lies with the revised theory. The reason is that the generalisation just noted does not invariably hold true, since it is violated in cases of diphthongisation. The inheritance of linkages from mother to daughter nodes appear to be only the normal, expected case, not an invariant law. Because of this, it would be wrong to have the inheritance of linkages from mother to daughter fall out directly from the formalism. Instead, we want a principle that makes it only the default case. The following convention is intended to do this:

(15) *Percolation Convention*
      When linkages are assigned to or removed from a node N, the assignments and deletions are automatically carried over to all nodes dominated by N

Here are two examples of how the Percolation Convention operates. In some languages (those without phonemic length or syllabicity contrasts), the CV tier is predictable in form, and can be projected from the segmental tier. The rules involved vary from language to language; see for instance Steriade (1984) and Dell & Elmedlaoui (1985) for possible algorithms. A typical rule would be one that projects a single C position for all [−consonantal] segments.

In such a language, a minimally redundant underlying representation would contain only segmental, not prosodic material. For example, the underlying representation for /p/ would be as in (16a). A projection rule

provides the /p/ with a C position (16b); and the Percolation Convention then associates all the lower-level tiers of /p/ to this C (16c):
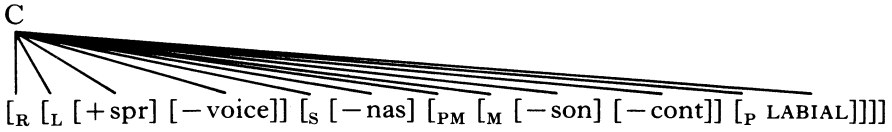
(16) a. Underlying /p/

$[_R [_L [+spr] [-voice]] [_S [-nas] [_{PM} [_M [-son] [-cont]] [_P LABIAL]]]]$

b. Projection of C position

C
|
$[_R [_L [+spr] [-voice]] [_S [-nas] [_{PM} [_M [-son] [-cont]] [_P LABIAL]]]]$

c. Percolation Convention

C
$[_R [_L [+spr] [-voice]] [_S [-nas] [_{PM} [_M [-son] [-cont]] [_P LABIAL]]]]$
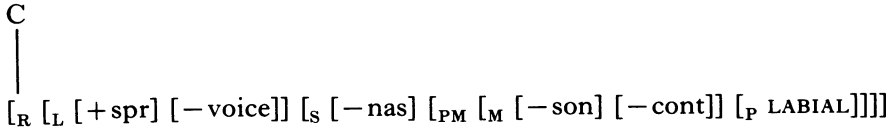
Similarly, when a /p/ segment has its Root node delinked by rule from its C position, the Percolation Convention delinks all its daughters as well:

(17) a. Delinking of Root node

C
$[_R [_L [+spr] [-voice]] [_S [-nas] [_{PM} [_M [-son] [-cont]] [_P LABIAL]]]]$

b. Percolation Convention

C

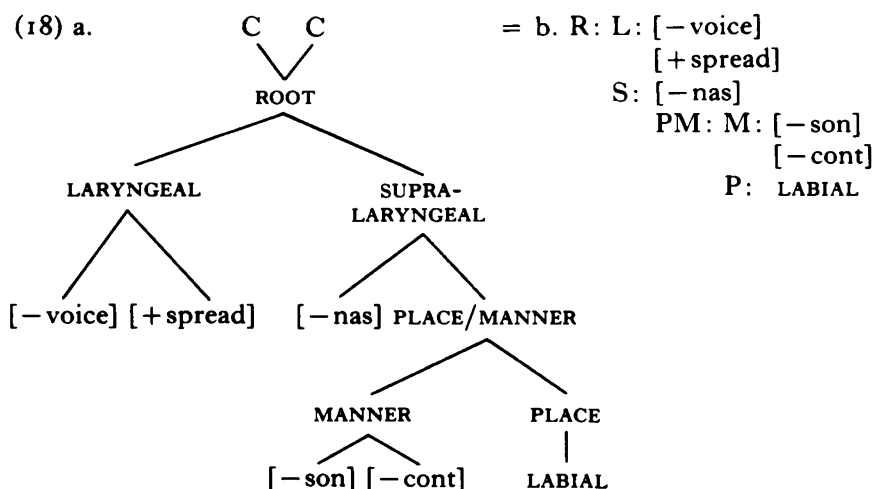$[_R [_L [+spr] [-voice]] [_S [-nas] [_{PM} [_M [-son] [-cont]] [_P LABIAL]]]]$
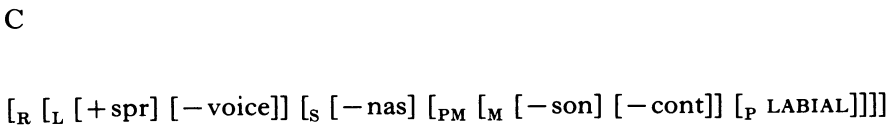
To summarise so far, I have separated out in the formalism the functions of feature grouping and temporal association; and have proposed a convention that establishes the normal correlation between the temporal associations of a mother node and those of its daughters.

6.2 Formalising the proposal

The formalism of the theory, however, is awkward. Since the representation of (16c) encodes only a single segment, the representation of a full string would be unmanageable, especially in cases where spreading applies. For this reason, I will propose a more tractable formalism.

Feature grouping can be expressed more concisely if we abandon trees and brackets, and adopt a simple outline form, as in (18b):

(18) a.

$$
\begin{array}{ll}
\text{C}\quad\text{C} & = \text{b. R: L: } [-\text{voice}] \\
\quad\vee & \qquad\qquad [+\text{spread}] \\
\quad\text{ROOT} & \quad\text{S: } [-\text{nas}] \\
& \qquad\text{PM: M: } [-\text{son}] \\
& \qquad\qquad\qquad [-\text{cont}] \\
& \qquad\text{P: LABIAL}
\end{array}
$$

LARYNGEAL   SUPRA-
                   LARYNGEAL

[−voice] [+spread]   [−nas] PLACE/MANNER

                MANNER   PLACE

   [−son] [−cont]   LABIAL

Just as in the full feature tree, the indentations of (18b) indicate that the Root node consists of a Laryngeal node and a Supralaryngeal node, the Supralaryngeal node consists of [nasal] and a Place/Manner node, and so on.

The proliferation of association lines created by the Percolation Convention can be made manageable if we adopt Halle & Vergnaud's (1980) idea of replacing association lines with coindexation. For example, the word *secret*, depicted with association lines in (19a), is represented with indices in (19b). In both cases, phonetic symbols abbreviate feature trees:

(19) a. C V V C C V C   b. C_1 V_2 V_3 C_4 C_5 V_6 C_7

         s i   k r ə t s_1 i_{23} k_4 r_5 $ə_6$ t_7
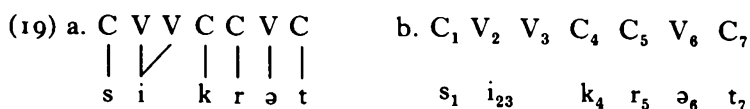
Indices are numbered consecutively for convenience; all that is crucial is that they be distinct.

The standard prohibition on crossed association lines can be expressed without the use of lines; it forbids temporally contradictory indices on different tiers:

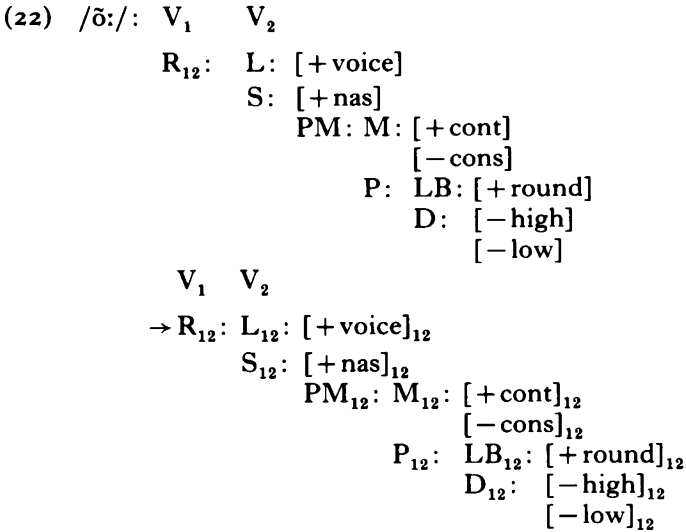(20) *i j   tier x

       j i   tier y
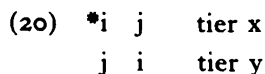
By combining the outline form for feature trees with the index notation, it becomes possible to depict phonological representations several segments long on the page, which is generally not possible with standard feature trees. To do this, we restate the Percolation Convention (15) as follows:

(21)   *Percolation Convention* (revised notation)
        When indices are assigned to or removed from a node N, the assignments and deletions are automatically carried over to all nodes dominated by N

An example appears in (22). Assuming a language in which length is phonemic, the underlying form for a long nasalised /õ:/ would include two V positions associated with the feature tree for /õ/. The Percolation Convention assigns the indices of the V positions to every node in the feature tree:

(22)   /õ:/: V_1 V_2

R_{12}:   L: [+voice]
            S: [+nas]
                PM: M: [+cont]
                            [−cons]
                        P: LB: [+round]
                              D: [−high]
                                    [−low]

V_1 V_2

→ R_{12}: L_{12}: $[+voice]_{12}$
              S_{12}: $[+nas]_{12}$
                  PM_{12}: M_{12}: $[+cont]_{12}$
                                        $[−cons]_{12}$
                              P_{12}: LB_{12}: $[+round]_{12}$
                                        D_{12}: $[−high]_{12}$
                                                  $[−low]_{12}$

The reader should bear in mind that the proposal made here is far less radical than would be suggested by the appearance of the formal representations. The real content of the proposal is the separation of the two functions of the feature tree: describing natural groupings of features, and linking the features to the prosodic tier. The radical-looking reformalisation is largely a matter of convenience and clarity.

I would add parenthetically my belief that current phonological representations are in need of reformalisation in any event. Using standard feature trees, it is quite difficult to express rules and derivations in a clear fashion. The alternative I propose has the additional advantage that it makes it easier to express rules and derivations in a precise way.

7 How the theory works

To illustrate the coindexation theory, it suffices to show two things. First, the theory should replicate the ability of standard feature trees to describe rules that spread non-terminal nodes, such as place assimilation. Second, the theory should also be able to express diphthongisation rules, a task for which standard feature trees are inadequate.

7.1 Spreading rules

I will illustrate how the coindexation theory treats spreading of non-terminal nodes with an ordinary example, place assimilation of nasals to a following obstruent, as in (23):

(23)   N → m /— labial obstruents
        → n /— alveolar obstruents
        → ŋ /— velar obstruents

To write rules with the index notation, I adopt the format in (24). Some basic assumptions about the notation deserve clarification: (a) unless otherwise indicated, indices in rules (such as i and j in (24)) are meant to be consecutive; (b) the structural change 'spread leftward' is horizontally aligned with the tier to which it applies; (c) the order in which the tiers appears on the page is not significant.

(24)   *Nasal Assimilation*

		$[-son]_j$	[sonorant] tier
	$[+nas]_i$		[nasal] tier
Spread leftward:		j	Place tier

This particular rule should be read as follows. Structural description: there are two consecutive segments, of which the first bears the feature value [+nasal] and the second bears the feature value [−sonorant]. I further assume (for concreteness only) that the nasal segment is under-specified for Place and thus bears no autosegment on the Place tier. Structural change: by 'spread leftward', it is meant that the Place tier specification of the obstruent acquires all indices borne by the nasal (here, just i). Thus following percolation, the obstruent supplies the Place features for both segments; in other words, the nasal assimilates to the obstruent in Place.

The Nasal Assimilation rule is used below to derive [ampa] from /aNpa/. For brevity, the feature trees for the vowels, as well as certain redundant features, have been suppressed. The underlying form for /aNpa/ presupposes a language in which CV positions can be projected by rule from the segmental string:

(25) /a R: L: [+voice]   R: L: [−voice]   a/
             S: [+nas]   S: [−nas]
                PM: M: [−cont]   PM: M: [−cont]
                       [+son]   [−son]
                                             P: LABIAL

This projection, with the coindexing that accompanies it, appears in (26):

(26) V_1 C_2 C_3 V_4

      a_1 R_2: L: [+voice] R_3: L: [−voice] a_4
             S: [+nas]   S: [−nas]
                PM: M: [−cont]   PM: M: [−cont]
                       [+son]   [−son]
                                              P: LABIAL

The Percolation Convention (21) then copies the indices through the trees:

(27) V_1 C_2 C_3 V_4

      a_1 R_2: L_2: [+voice]$_2$ R_3: L_3: [−voice]$_3$ a_4
             S_2: [+nas]$_2$ S_3: [−nas]$_3$
                PM_2: M_2: [−cont]$_2$ PM_3: M_3: [−cont]$_3$
                       [+son]$_2$ [−son]$_3$
                                              P_3: LABIAL$_3$

Next, Nasal Assimilation (24) applies, with $\mathbf{i} = 2$ and $\mathbf{j} = 3$. By the rule, the Place autosegment indexed 3 also acquires the index 2:

(28) V_1 C_2 C_3 V_4

      a_1 R_2: L_2: [+voice]$_2$ R_3: L_3: [−voice]$_3$ a_4
             S_2: [+nas]$_2$ S_3: [−nas]$_3$
                PM_2: M_2: [−cont]$_2$ PM_3: M_3: [−cont]$_3$
                       [+son]$_2$ [−son]$_3$
                                              P_{23}: LABIAL$_3$

Following assimilation, the Percolation Convention can apply again to percolate the index **2** down the tree, ensuring that the Place specification for the newly assimilated nasal is Labial:

(29) V_1 C_2 C_3 V_4

      a_1 R_2: L_2: [+voice]$_2$ R_3: L_3: [−voice]$_3$ a_4
             S_2: [+nas]$_2$ S_3: [−nas]$_3$
                PM_2: M_2: [−cont]$_2$ PM_3: M_3: [−cont]$_3$
                       [+son]$_2$ [−son]$_3$
                                              P_{23}: LABIAL$_{23}$

The end result is [ampa], which is what we want. Other cases of multi-feature assimilation can be described with similar rules and derivations.

7.2 Diphthongisation rules

Consider next the task for which standard feature trees appear to be inadequate, expressing diphthongisation rules. I will formalise here a rule noted above, the Old French diphthongisation of /eː oː/ to [ei ou]. For concreteness, I posit that [high] is underspecified, with the value [+high] filled in by a default rule. Nothing crucially hinges on this, however. The diphthongisation rule can be expressed as follows:

(30) *Old French Diphthongisation*

$$V_i \; V_j \qquad \text{CV tier}$$

$$[-\text{low}]_{ij} \quad [\text{low}] \text{ tier}$$

$$\text{Delete j:} \quad [-\text{high}]_{ij} \quad [\text{high}] \text{ tier}$$

In words, the rule says the following: (a) Structural description: the feature values [−low] and [−high] are linked to consecutive V slots; i.e. we have a long mid vowel; (b) Structural change: the index **j** is deleted on the [high] tier. This means that the second mora of the long mid vowel becomes unspecified for height. When the default rule assigning [+high] applies, this will result in the second mora of the long vowel being raised. The rule would apply to long /oː/ as follows:

(31) a. $V_1 \; V_2$ underlying form: /oː/

$$R_{12} \text{: S: PM: M:} \quad [-\text{cons}]$$
$$\text{P:} \quad \text{LB:} \quad [+\text{round}]$$
$$\text{D:} \quad [-\text{high}]$$
$$[-\text{low}]$$

b. $V_1 \; V_2$ Percolation Convention

$$R_{12} \text{: } S_{12} \text{: } PM_{12} \text{: } M_{12} \text{: } [-\text{cons}]_{12}$$
$$P_{12} \text{: } LB_{12} \text{: } [+\text{round}]_{12}$$
$$D_{12} \text{: } [-\text{high}]_{12}$$
$$[-\text{low}]_{12}$$

c. $V_1 \; V_2$ Diphthongisation

$$R_{12} \text{: } S_{12} \text{: } PM_{12} \text{: } M_{12} \text{: } [-\text{cons}]_{12}$$
$$P_{12} \text{: } LB_{12} \text{: } [+\text{round}]_{12}$$
$$D_{12} \text{: } [-\text{high}]_1$$
$$[-\text{low}]_{12}$$

d. $V_1 \; V_2$ Default [+high] assignment = [ou]

$$R_{12} \text{: } S_{12} \text{: } PM_{12} \text{: } M_{12} \text{: } [-\text{cons}]_{12}$$
$$P_{12} \text{: } LB_{12} \text{: } [+\text{round}]_{12}$$
$$D_{12} \text{: } [-\text{high}]_1 \; [+\text{high}]_2$$
$$[-\text{low}]_{12}$$

The crucial part of the derivation is this: since [high] is in effect linked directly to the prosodic tier (by coindexation and percolation), it may diphthongise independently of other features, unlike in the original theory proposed by Clements.

Observe also that in the analysis we need not underspecify the value [+high]; assuming that [−high] is underspecified, we would write the rule as in (32):

(32) V_i V_j CV tier

                   $[-low]_{ij}$ [low] tier

Insert $[+high]_j$:   —   [high] tier

After this rule applied, the default rule for [−high] would then insert a [−high] value, indexed **i**. A fully specified representation could also yield an acceptable analysis, although here the rule must both delete an index and insert a [+high] autosegment.

The derivation also justifies a claim made earlier: after diph-thongisation, a daughter node may fail to bear an index borne by its mother. In (31c), the feature [−high] is only indexed **1**, while its mother node is indexed **1, 2**. It is for this reason that the Percolation Convention is formulated as in (21): only indices that are initially assigned or altered by rule get percolated down the tree. The ability of the coindexation theory to keep indices from being automatically inherited down from mother to daughter nodes is what crucially distinguishes it from Clements' original theory, in which downward inheritance is an automatic consequence of the formalism. The claim made here is that avoiding this inheritance is necessary for an adequate account of diphthongisation.

Other diphthongisation rules are also straightforwardly expressed under the coindexation theory. In Jutland Danish (Andersen 1972), we find diphthongisation of voicing; the long high vowels lose voicing in their second moras: /iː yː uː/ → [ii̥ yy̥ uu̥]. Assuming that [+voice] is under-specified in vowels, the rule can be expressed as follows:

(33) *Danish Voicing Diphthongisation*
                    V_i V_j CV tier

                   $[+high]_{ij}$ [high] tier

Insert $[-voice]_j$:   —   [voice] tier

That is, in a long high vowel, specify the second mora as [−voice].

Icelandic Preaspiration, discussed above, also has a straightforward account:

(34) *Icelandic Preaspiration*
                    C_i C_j CV tier

Delete i: $[-cont]_{ij}$ Place/Manner tier

           $\begin{bmatrix} +spread \\ -voice \end{bmatrix}_{ij}$ Laryngeal tier

This rule delinks the Place/Manner autosegment from the first half of a geminate voiceless aspirated stop, converting /pp tt kk/ to [hp ht hk].

7.3 Summary

This concludes the basic presentation of the proposal. To summarise, I will review the properties attributed to feature trees in the literature, discussing what is changed and what remains the same under the coindexation theory.

(a) *Natural feature groupings*: Feature trees characterise the groupings of features accessed by phonological rules. This continues to be the case under the revised theory.

(b) *Taxonomy*: Feature trees make predictions about logical dependencies in feature specifications. In particular, if feature F is dominated by node N, then F may not be distinctive for segments that lack N. An example is the Coronal node: there are convincing arguments that when properly defined, the features [strident], [anterior] and [distributed] are relevant only for coronals. This follows from the theory, since these features occur dominated by Coronal (Steriade 1985). Again, nothing is changed under the revision proposed here.

(c) *Locality*: As work by Archangeli & Pulleyblank (forthcoming) and Steriade (1987a) makes clear, feature trees provide the basis for a plausible theory of non-local rule application. Although particular accounts vary, the basic idea is as follows: two autosegments A and B on tier T may be involved in a rule if either (a) A and B belong to string-adjacent segments (the normal requirement); or (b) no autosegment in T separates A and B ('long-distance' rules). Feature trees are crucial here, in that they specify a limited set of tiers that determine the possible channels of long-distance rule application. Nothing is changed in this regard under a coindexation theory.

(d) *Docking*: The remaining function that has been attributed to feature trees is that of providing the feature-bearing units for every feature and class node: the 'T-bearing units' for a tier T are claimed to be the nodes that immediately dominate T within the tree. It is here that my proposal differs. I have argued that if we are to have an adequate account of diphthongisation, the set of T-bearing units must include the elements of the prosodic tier. Whether the class nodes of the feature tree must also serve as T-bearing units, and if so, which ones, remains an open question.

It should be clear, then, that the proposal made here is far less radical than the superficial appearance of the representations would suggest, since feature trees still carry out at least three of the four functions that they serve in the original theory. Thus they continue to serve as a central aspect of phonological representation.

The remainder of this article treats additional issues related to the basic proposal. In §8, I discuss a class of diphthongisation rules that are not amenable to treatment under standard feature theories, and propose an account based on the theory of particle phonology. §9 attempts to answer

a number of further questions raised by the coindexation formalism. Finally, in §10 I discuss the 'two-root' theory of diphthongisation proposed in Selkirk (1988).

8 More complex diphthongisations

A full account of diphthongisation must be able to treat the more elaborate cases, found in vowel systems where most or all of the long vowels undergo diphthongisation. For example, in Lund Swedish (discussed below), the entire long vowel inventory diphthongises as follows:

(35)　/iː/ → [ei]　/yː/ → [ey]　/ʉː/ → [eʉ]　/uː/ → [eu]
　　　/eː/ → [ɛe]　/øː/ → [ɛø]　　　　　　/oː/ → [ɛo]
　　　/ɛː/ → [æɛ]　　　　　　　　　　　　/ɒː/ → [æo]

To handle such examples adequately, one must adopt a theory of vowel features rather different from the standard set of *SPE*. In what follows, I adopt a version of the theory of particle phonology, proposed by Schane (1984a).

8.1 Particle phonology

Particle phonology posits that vowels are specified not with binary features, but with combinations of basic 'particles' of vowel quality. The three particles are **U**, which indicates rounding; **I**, which indicates frontness; and **A**, which indicates lowness in varying degrees. Below, the vowel inventories of three languages are expressed with particles:

(36)　a. Spanish:　i　　u = I　　　　　　　　　U
　　　　　　　　 e　a　o　 IA　　　　　A　 UA
　　　 b. Italian:　i　　u = I　　　　　　　　　U
　　　　　　　　 e　　o　 IA　　　　　　　 UA
　　　　　　　　 ɛ　a　ɔ　 IAA　　　　AA　 UAA
　　　 c. Finnish:　i y　u = I　　 IU　　　　　　U
　　　　　　　　 e ø　o　 IA　　 IUA　　　　UA
　　　　　　　　 æ　　ɑ　 IAA　　　　　AA

Observe that a vowel may contain multiple **A** particles, depending on the number of contrasting degrees of height in the language. Instances of three **A** particles per vowel appear below.

　　Schane's proposal involves a number of logically distinct claims, not all of which will be adopted here. The following is an attempt to separate them.

　　First, Schane's original theory incorporates a non-prosodic account of

vowel length, which he has subsequently abandoned in favour of a standard CV account (Schane 1987). I will use CV representations here.

The second point concerns the particles **I** and **U**. Backness and rounding are believed to form only binary contrasts, and for this reason at most one **I** or **U** particle may appear per vowel. Thus **I** and **U** act much like binary features. Indeed, as Goldsmith (1987) points out, **I** is essentially the same thing as [−back], and **U** the same as [+round], in underspecification theories that allow only the values [−back] and [+round] to appear in the phonology. Without taking a stand on the issue of one-valued features, I will use [−back] and [+round] below instead of **I** and **U** particles, to emphasise their binary nature. (For further discussion see Goldsmith 1985, den Dikken & van der Hulst 1988 and Steriade 1981.)

The really crucial part of Schane's theory is its representation of height. Unlike backness and rounding, height often involves a contrast among multiple values, and the choice of phonological features to characterise the height continuum has always been a difficult issue.

The crucial observation behind the theory is that there exist many phonological rules that shift a column of vowels up or down one position along a continuum of height, as in /i/ → [e], /e/ → [ɛ], /ɛ/ → [æ]. Such rules are common; indeed, a parallel upward or downward shift may be the most frequent kind of rule affecting height in a column of front or back vowels; cf. Saltarelli (1973); Lipski (1973); McCawley (1973); Schane (1984a, b); Hyman (1988). It is possible to employ standard vowel features in an ad hoc way to account for such changes; see for example Yip (1980), and for cogent criticism of this approach McCawley (1973). However, height shifts of this sort are sufficiently ordinary and characteristic that they should receive a maximally simple formal interpretation under the theory. This is available in particle theory, which expresses such rules as the addition or deletion of **A** particles.

A number of accounts of vowel height that resemble Schane's in certain respects (e.g. Kaye *et al.* 1985; Anderson & Durand 1986: 32) posit a maximum of one **A** particle. Such accounts cannot express the raising or lowering of a column of vowels without additional stipulations or interpretive conventions.

An earlier theory that can also account for parallel height shifts posits a single height feature with multiple integer values (see for example Contreras 1969). Particle phonology resembles such a theory, but is not a notational variant, for the following reason: unlike a n-ary height feature, particle notation can express partial assimilations in height as auto-segmental spreading; that is, as spreading of individual particles. To describe such changes with a multivalued feature would force us to abandon the general principle that assimilation is due to spreading.

There is an issue in particle theory that remains to be worked out: sometimes the particles for height must express highness rather than lowness. Such would be the case for the rule of Southern Sotho (Doke & Mofokeng 1957) that raises /ɛ ɔ/ to [e o] before /i u ɪ ʊ/ in the next syllable (vowel inventory: /i u ɪ ʊ e o ɛ ɔ a/). This is clearly a case of

spreading of relative height rather than relative lowness, suggesting that particle theory will have to be extended (via 'antiparticles' or otherwise) to accommodate height shifts in both directions.

There is no inherent incompatibility between particle phonology and the hierarchical model of segment structure advocated here: the particles are simply substituted for the relevant vowel features, as in (37). As noted above, in this article I will use particles only for height:

(37)   a. /ø:/ in features:
           V_1 V_2

       R_{12}: S_{12}: PM_{12}: M_{12}: $[-\text{cons}]_{12}$
                           P_{12}: L_{12}: $[+\text{round}]_{12}$
                                       D_{12}: $[-\text{back}]_{12}$
                                                 $[-\text{high}]_{12}$
                                                 $[-\text{low}]_{12}$

       b. /ø:/ in particles:
           V_1 V_2

       R_{12}: S_{12}: PM_{12}: M_{12}: $[-\text{cons}]_{12}$
                           P_{12}: L_{12}: $[+\text{round}]_{12}$
                                       D_{12}: $[-\text{back}]_{12}$
                                                 A_{12}

Equipped with this model, we can now consider some more complex cases of diphthongisation.

8.2 Eastern Finnish

In eastern dialects of Finnish (Kiparsky 1968), all long non-high vowels diphthongise, with the first mora becoming one value higher in the vowel space: /e: ø: o: æ: ɑ:/ → [ie yø uo eæ oɑ]. The long vowel inventory, with its feature and particle specifications, is shown below:

(38)   /i:/ $= [-\text{back}]$ /y:/ $= [-\text{back}]$ /u:/ $= [+\text{round}]$
                                          $[+\text{round}]$

       /e:/ $= [-\text{back}]$ /ø:/ $= [-\text{back}]$ /o:/ $= [+\text{round}]$
              A $[+\text{round}]$ A
                                           A

       /æ:/ $= [-\text{back}]$ /ɑ:/ $= AA$
              AA

The diphthongisation rule has a straightforward structural change: we simply delink an **A** particle from the first mora of a long vowel. Using the representations adopted here, this can be expressed as follows:

(39)   *Eastern Finnish Diphthongisation*

                          V_i V_j CV tier
           Delete i: A_{ij} Height tier

The rule would apply to long /e:/ as follows:

(40) a. Input: /e:/

$$V_1 \quad V_2$$

$$R_{12}: \ S_{12}: \ PM_{12}: \ M_{12}: \ [-\text{cons}]_{12}$$
$$P_{12}: \ D_{12}: \ A_{\underline{12}}$$
$$[-\text{back}]_{12}$$

    b. Output: [ie]

$$V_1 \quad V_2$$

$$R_{12}: \ S_{12}: \ PM_{12}: \ M_{12}: \ [-\text{cons}]_{12}$$
$$P_{12}: \ D_{12}: \ A_2$$
$$[-\text{back}]_{12}$$

Owing to the diphthongisation rule, the first V position in the output form is linked to [−back] and no **A** particles, and thus is realised as [i]. The second V position is linked to [−back] and a single **A**, and thus is realised as [e].

Note that we again have a case in which a mother node (for example, the Dorsal node) bears indices not borne by a daughter. As noted earlier, it is this situation which can be described using a coindexation theory, but not using orthodox feature trees.

The other vowels in the Eastern Finnish system are also converted by (39) to the correct output forms, with the exception of underlying /ɑ:/, which becomes *[ʌɑ]. Noting that /ʌ/ is not a possible vowel in this dialect, we may plausibly add a fix-up rule, which assigns [+round] to back vowels whose only particle is a single **A**. Letting the notation /P/ stand for exactly one particle, we can express this rule as follows:

(41)   ø$_j$ [back] tier

                         /A$_i$/ Height tier

Insert [+round]$_i$:   —   [round] tier

This converts */ʌɑ/ to [oɑ], the correct form.

8.3 Lund Swedish

In certain southern dialects of Swedish, the entire inventory of long vowels undergoes diphthongisation. I describe here the rules for the dialect of Lund; the very similar nearby Malmö dialect is discussed in Bruce (1970), Lindau (1978) and Yip (1980). The data here were provided by M. Lindau, who is a native speaker of the Lund dialect.

There is evidence that diphthongisation is a productive synchronic rule in this dialect. Lindau notes that educated speakers often shift their pronunciations, producing long monophthongs in formal contexts and diphthongs in informal speech. Moreover, the rule is supported by alternations: when long vocalic nuclei are shortened before clusters,

diphthongisation is inapplicable, and the underlying monophthongal quality surfaces: [veit] 'white' ~ [vit-t] 'white-NEUT', [lɛed-a] 'lead-INF' ~ [led-də] 'lead-PAST', [mæɛt-a] 'measure-INF' ~ [mɛt-tə] 'measure-PAST'.

The long vowels of Lund Swedish diphthongise as shown in (35) (repeated here as (42)):

(42) /iː/ → [ei]   /yː/ → [ey]   /ʉː/ → [eʉ]   /uː/ → [eu]
      /eː/ → [ɛe]   /øː/ → [ɛø]   /oː/ → [ɛo]
      /ɛː/ → [æɛ]   /ɒː/ → [æo]

Some phonetic notes: in the high front vowel /y/ the lips are rounded and protruded. The vowel /ʉ/ is also high and front, but the lips are unrounded, and form a weak bilabial constriction of the kind used for [β] (Fant 1973: 192–193). Formally, I assume that both /y/ and /ʉ/ contain a Labial autosegment, but that only /y/ is [+round]. Thus /y/ will be represented as in (43a), /ʉ/ as in (43b). The back vowel /u/ is also labial but unrounded (cf. Fant), and is represented as in (43c):

(43)   a. /y/   b. /ʉ/   c. /u/
           LABIAL, [−back]   LABIAL, [−back]   LABIAL
           |
           [+round]

The full set of feature and particle specifications for the Lund vowels is therefore as in (44). Note that the vowel [æ] is not underlying, but is derived by Diphthongisation; hence there are just three contrasting values for height.

(44)

/iː/ = [−back] /yː/ = LABIAL   /ʉː/ = LABIAL   /uː/ = LABIAL
                      [+round]   [−back]
                      [−back]

/eː/ = [−back] /øː/ = LABIAL   /oː/ = LABIAL
       A   [+round]   [+round]
                      [−back]   A
                      A

/ɛː/ = [−back] /œː/ = LABIAL   /ɒː/ = LABIAL
       AA   [+round]   [+round]
                      [−back]   AA
                      AA

[æ] = [−back]
       AAA

Given these representations, Lund diphthongisation can be expressed with two basic rules. One shifts the first mora of a long vowel down one position, by adding an **A** particle coindexed with it:

(45) *Lund Swedish Lowering*

$$\sigma_{ij} \qquad \text{Syllable node}$$

$$V_i \quad V_j \qquad \text{CV tier}$$

Insert A_i: —   Height tier

The other rule delabialises the first mora of all long nuclei by delinking the Labial feature complex:

(46) *Lund Swedish Delabialisation*

$$\sigma_{ij} \qquad \text{Syllable node}$$

$$V_i \quad V_j \quad \_ \quad \text{CV tier}$$

Delete i: LABIAL$_{ij}$ Labial tier

I assume that following delabialisation, default rules apply. Since all non-Labial vowels are front, a default rule assigns [−back] to them.

The rules are illustrated below with the derivation /oː/ → [ɛo]:

(47) a. $V_1 \quad V_2$ underlying form

       R_{12}: S: PM: M: [−cons]

                   P: L: [+round]

                   D: A   = /oː/

    b. $V_1 \quad V_2$ Percolation

                                         Convention (21)

       R_{12}: S_{12}: PM_{12}: M_{12}: $[−\text{cons}]_{12}$

                        P_{12}: L_{12}: $[+\text{round}]_{12}$

                        D_{12}: A_{12}

    c. $V_1 \quad V_2$ Lowering (45)

       R_{12}: S_{12}: PM_{12}: M_{12}: $[−\text{cons}]_{12}$

                   P_{12}: L_{12}: $[+\text{round}]_{12}$

                   D_{12}: $A_{12}A_1$

    d. $V_1 \quad V_2$ Delabialisation

                                         (46)

       R_{12}: S_{12}: PM_{12}: M_{12}: $[−\text{cons}]_{12}$

                   P_{12}: L_2: $[+\text{round}]_{12}$

                   D_{12}^{-}: $A_{12}A_1$

    e. $V_1 \quad V_2$ Percolation

                                         Convention

       R_{12}: S_{12}: PM_{12}: M_{12}: $[−\text{cons}]_{12}$

                   P_{12}: L_2: $[+\text{round}]_2$

                   D_{12}: $A_{12}A_1$

f. V_1 V_2 Default assignment
                                                     of [−back] to
                                                     non-labial vowels

R_{12}: S_{12}: PM_{12}: M_{12}: [−cons]$_{12}$
$\phantom{R_{12}: S_{12}: PM_{12}:}$ P_{12}: L_2: [+round]$_2$
$\phantom{R_{12}: S_{12}: PM_{12}:}$ D_{12}: $A_{12}A_1$
$\phantom{R_{12}: S_{12}: PM_{12}: D_{12}:}$ [−back]$_1$ = [εo]

The case of [æo], derived from /ɒ:/, requires an additional rule, since Lowering and Delabialisation alone would derive *[æɒ], with a low second mora. The additional rule must delink an A particle from a second mora specified [+round], **AA**. A similar rule barring low rounded vowels from diphthongs appears in the next section.

All four rules of the analysis (Lowering (45), Delabialisation (46), default insertion of [−back] I, and the adjustment rule of the preceding paragraph) make crucial use of the theory advocated here: each rule must be able to adjust associations between vowel features/particles and V positions, even though the features and particles appear deeply embedded in the feature tree. The analysis also makes crucial use of particle phonology to express a rule shifting all vowel heights down by one position.

8.4 Quebec French

The most elaborate example of diphthongisation known to me is found in Quebec French. The following formalisation is based primarily on Dumas' (1981) intensive study, as well as Dumas (1976), Rochette (1980) and Walker (1984).

Unlike continental French, Quebec French has a pervasive distinction of vowel length. Scholars disagree on the extent to which this distinction is phonemic. Rochette (1980), noting the degree of integration of English borrowings with unpredictable vowel length, argues that most long vowels are separate phonemes. Although the phonemic status of long vowels is not fully agreed upon, all scholars agree in positing a rule that diphthongises long vowels in stressed syllables. According to Dumas, diphthongisation takes the following pattern:

(48)	Front unrounded	Front rounded	Back rounded
High	/iː/	/yː/	/uː/
Upper mid	/eː/ [ɪi]	/øː/ [ʏy]	/oː/ [ʊu]
Lower mid	/ɛː/ [ɛi]	/œː/ [œy]	/ɔː/ [ɔu]
Low	[ai]	[ay]	/ɒː/ — [ɑu]

Diphthongisation is highly productive, and produces numerous alternations such as *bêtise* [bɛːtˢíis] 'nonsense' ~ *bête* [báit] 'stupid', *passage* [pɒːsáž] 'passage' ~ *passent* [páus] 'pass-3 PL' (Dumas 1981: 3).

In arranging the chart I have followed Dumas (1976) in abstracting away from the differences between [e] and [ɪ], [ø] and [ʏ], and [o] and [ʊ]. Dumas (1981: 12–17) demonstrates that these pairs stand for identical vowel qualities. The practice of using separate symbols for them is a convention, intended to reflect their distinct phonological origin and behaviour. I also follow Dumas (1981: 34) in assuming that the vowel /ɒː/ is derived from /aː/ at a deeper level of representation by a rule of Backing.

The overall pattern of diphthongisation can be stated, following Dumas, as follows: (a) the first mora of a long vowel is lowered one degree (except for /ɒː/, where further lowering is impossible); (b) the second mora is raised to high. However, this description of the second mora, incorporated in (48) for brevity, is actually an oversimplification: the second mora of a long vowel is actually raised variably; i.e. not at all, part way to high, or all the way to high. Thus phonemic /ɛː/ may surface as [aɛ], [ae] or [ai]; and similarly for the other non-high vowels (Rochette 1980: 28–29; Dumas 1981: 12; Walker 1984: 68–69).

To account for these facts, I propose the following analysis. The specifications for the vowel qualities of Quebec French are as in (49)

(49)

[i]	= [−back]	[y]	= [−back] [+round]			[u]	= [+round]
[eː,ɪ]	= [−back] A	[øː,ʏ]	= [−back] [+round] A			[oː,ʊ]	= [+round] A
[ɛ]	= [−back] AA	[œ]	= [−back] [+round] AA			[ɔ]	= [+round] AA
[a]	= [−back] AAA			[ɑ] = AAA	[ɒ]	= [+round] AAA

Diphthongisation is carried out by two rules. The first lowers the first mora of a long vowel one slot on the chart, by adding an **A** particle. Since the particle combination AAAA is ill-formed (being lower than the maximum possible value), I assume that the rule is blocked when the input is AAA. As a result, the input forms /ɒː/ and /ɔː/ are neutralised as [ɑu]:

(50) *Quebec French Lowering*

σ_{ij} Syllable node   where σ is stressed

V_i V_j CV tier

Insert A_i: —   Height tier

The second rule freely delinks any number of **A** particles from the second mora. As a way of allowing any number of particles to be delinked, I suggest that the rule is both optional and iterative:

(51)   *Quebec French Raising* (optional, iterative)

σ_{1j} Syllable node   where σ is stressed

V_i V_j CV tier

Delete j: A_j Height tier

The following are derivations for the rules applied to /y:/ and to /ɛ:/:

(52)   a. Underlying /y:/
V_1 V_2

R_{12}: S: PM: M: [−cons]
                    P: L: [+round]
                         D: [−back]

Underlying /ɛ:/
V_1 V_2

R_{12}: S: PM: M: [−cons]
                    P: D: [−back]
                              AA

b. Percolation Convention
V_1 V_2

R_{12}: S_{12}: PM_{12}: M_{12}: [−cons]$_{12}$
                         P_{12}: L_{12}: [+round]$_{12}$
                                   D_{12}: [−back]$_{12}$

V_1 V_2

R_{12}: S_{12}: PM_{12}: M_{12}: [−cons]$_{12}$
                         P_{12}: D_{12}: [−back]$_{12}$
                                   $A_{12}A_{12}$

c. Addition of **A** particle to first mora
V_1 V_2

R_{12}: S_{12}: PM_{12}: M_{12}: [−cons]$_{12}$
                         P_{12}: L_{12}: [+round]$_{12}$
                                   D_{12}: [−back]$_{12}$
                                        $\underline{A_1}$

V_1 V_2

R_{12}: S_{12}: PM_{12}: M_{12}: [−cons]$_{12}$
                         P_{12}: D_{12}: [−back]$_{12}$
                                   $A_{12}A_{12}\underline{A_1}$

d. Free delinking of **A** particles from second mora

— V_1 V_2

$(= [\gamma y])$ R_{12}: S_{12}: PM_{12}: M_{12}: $[-cons]_{12}$

P_{12}: D_{12}: $[-back]_{12}$

$A_{1(2)} A_{1(2)} A_1$

$(= [a\varepsilon], [ae]$ or $[ai])$
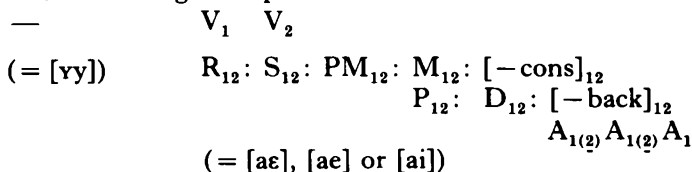
One further fact remains to be accounted for: the lower rounded vowels /œ: ɔ: ɒ:/ lose rounding in their first moras under diphthongisation: [ay au ɑu]. This can be derived by adding a rule that delinks [+round] from the first mora when it is linked to three **A** particles. Dumas (1981: 52) suggests this may reflect a universal constraint on the distribution of rounding.

To conclude this section: some fairly complex diphthongisation rules, affecting most or all the long vowels in a language, receive straightforward interpretations provided we adopt two formal assumptions: (a) the proposal made here to link all tiers directly to the prosodic tier, using coindexation and the Percolation Convention; (b) the use of multiple particles to characterise vowel height.

9 Further issues in coindexation theory

An attempt to reformalise phonological representations leads to many questions, some substantive, others matters of formalisation. This section discusses some of these issues.

9.1 Affricates and other contour segments

Some languages contrast affricates with articulatorily similar stop–fricative sequences, as in Polish /č/ *vs.* /tš/ (Brooks 1964). In classical CV phonology, such a distinction would result from a different number of C positions linked to a basic /tš/ sequence, as in (53) (Clements & Keyser 1983: 34–35):

(53) a. /tš/: C C   b. /č/:   C
        | | ╱╲
        t š   t   š
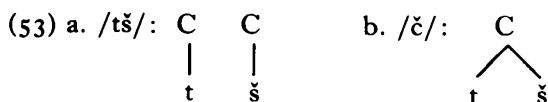
Sagey (1986) observes that feature trees permit an alternative representation for affricates. The affricate /č/ involves just one Root node, with two sequential values for the feature [continuant] embedded within the same feature tree. The claim is that feature trees may include a time dimension as well as grouping information. I will refer to such representations, following Sagey, as CONTOUR SEGMENTS. A contour segment
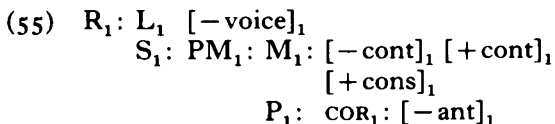
representation for /č/ appears in (54); the boldfaced values of [continuant] are sequenced in time:

(54)

```
                        C
                        |
                      ROOT
                    /      \
            LARYNGEAL      SUPRA-
                 |        LARYNGEAL
                 |          /    \
            [−voice]   [−nas]   PLACE/MANNER
                                  /       \
                              MANNER      PLACE
                               / \          |
                     [−cont] [+cont]    CORONAL
                                          /   \
                                    [−ant]   [+distr]
```
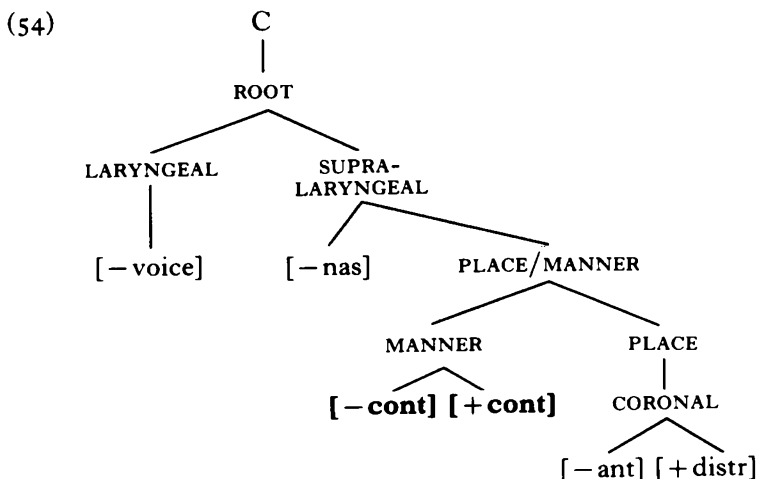
Such an analysis generalises in an obvious way to other contour segments, such as prenasalised stops.

A number of arguments support contour segment representations. Sagey notes that contour segments often are derived by spreading of a single feature, as in the cases of contour nasality discussed by Anderson (1974, 1976). This is predicted by representations like (54), but not by two-root representations like (53a). McCarthy & Prince (forthcoming) observe that affricates are never split up by mapping processes in non-concatenative morphological systems; this is predicted by (54), but not by the two-root representation. McCarthy & Prince also note that only representations like (54) are compatible with the moraic theory of segment structure.

Consider now the question of how the feature sequence in a contour segment should be indexed. I conjecture that the two feature values receive the same index, with their temporal ordering determined simply by their ordering within the representation. With this indexation, /č/ would appear as in (55):

(55) R_1: L_1 $[-voice]_1$
       S_1: PM_1: M_1: $[-cont]_1$ $[+cont]_1$
                          $[+cons]_1$
                 P_1: COR_1: $[-ant]_1$

The claim implicit in (55) is as follows: since it bears only one index, an affricate is the immediate temporal successor of the segment on its left, and predecessor of the segment on its right. However, with regard only to the feature [continuant], an affricate will function as [−continuant] for rules applying at its left edge, and as [+continuant] for rules applying

at its right edge (Sagey 1986). Although the matter is controversial (Archangeli 1987; Hualde 1988), I believe these are the right typological predictions to be made about affricates and similar segments.
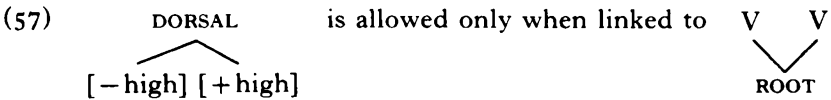
9.2 Diphthongs as contour segments

The contour-segment theory just discussed appears to undermine the basic point of this article. Returning for the moment to orthodox feature tree theory, consider the following schematic contour-segment representation for the diphthong /ei/:

(56)
```
        V   V
         \ /
          V
         ROOT
          |
          :
          |
        DORSAL
         / \
   [−high] [+high]
```
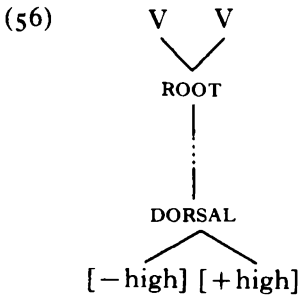
Here, the diphthong is treated like an affricate, with sequential values only for the feature [high]. Such a representation could easily be derived from /iː/ or /eː/ by inserting the appropriate feature value for [high] into the tree. Thus we would be able to express diphthongisation without adopting a coindexation theory.

The problem with this counterproposal is that it fails to account for the observation made above in §5: rules of diphthongisation apply only to long vowels; more generally, diphthongs virtually always occupy two prosodic positions. Consider how this generalisation must be stated in a theory that represents diphthongs as in (56): a contour segment for vowel features is allowed only under a Root node that is doubly linked. This is illustrated graphically in example (57):

(57)
```
        DORSAL        is allowed only when linked to    V   V
         / \                                             \ /
   [−high] [+high]                                        V
                                                        ROOT
```

Such long-distance dependencies of branching within the feature tree do not appear to be attested elsewhere in phonology. Moreover, (57) is a rather baroque way of stating what is a very simple and characteristic constraint: prosodic positions may bear only one value per vowel feature. Coindexation theory allows us to state the crucial generalisation directly, since the vowel features and prosodic positions are linked to each other (i.e. coindexed) by the Percolation Convention. The fact that vowel features are almost always constrained to appear one per V position is the crucial indicator that they are in fact linked to V positions, as claimed here.

To summarise, in the coindexation theory, diphthongs *are* contour segments, but not with the structure of (56); rather, the vowel features that change in the course of a diphthong are independently linked to the prosodic tier. In addition, I am claiming that diphthongs and affricates are different: in many languages, a single prosodic position may be linked to a [−continuant] [+continuant] sequence, but for the great majority of languages, a prosodic position may be linked to only one vowel feature.

9.3 Moraic theory

The discussion thus far has employed CV formalism for simplicity of exposition. However, there is no reason why a coindexation theory could not be implemented under alternative theories of the prosodic tier, such as X theory or moraic theory. In the latter case, we must attach indices to syllable nodes for onset segments, since moraic theory assigns no prosodic position to onsets. For example, the word *secret*, represented in CV theory in (58a), would appear as in (58b) in moraic theory:

(58) a. $C_1\ V_2\ V_3\ C_4\ C_5\ V_6\ C_7$

$s_1\ i_{23}\quad k_4\ r_5\ \vartheta_6\ t_7$

b. $\sigma_{123}\qquad \sigma_{4567}$

$\mu_2\ \mu_3\qquad \mu_6\ \mu_7$

$s_1\ i_{23}\quad k_4\ r_5\ \vartheta_6\ t_7$
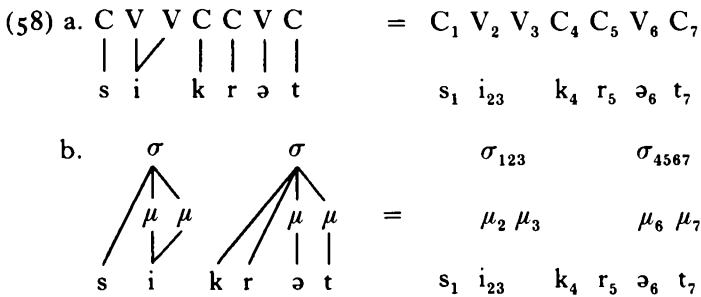
For clarity, I have attached to each syllable node the indices of all the segments it dominates. Coindexation proceeds in moraic theory as part of syllabification, so that a consonant syllabified in onset position is coindexed with the syllable node.

To my knowledge, none of the discussion above would be materially affected by the shift to moraic representations, nor would the coindexation proposal alter any of the arguments for moraic theory in the literature (see Hyman 1985; Hayes 1989; McCarthy & Prince forthcoming). It should be noted that the theory of Steriade (1987b), which I have argued against, is not compatible with moraic theory, since it uses X-tier positions rather than Root nodes as the unifying point for the features.

9.4 Global effects

As J. Itô and an anonymous reviewer have pointed out, the coindexation theory gives rise to unwanted global effects. As an example, consider two cases in which the cluster [bm] is derived by rule. In English, it may derive from assimilation of a /d/ to a following /m/, as in fast-speech *good man* [gʊbmæn]. In various German dialects, [bm] may derive from /bn/ by

progressive assimilation of /n/: *haben* [habm] 'to have'. Schematic derivations for both cases are shown below:

(59)

a. C_1 C_2 Input: /dm/

  R_1: S_1: $[-nas]_1$ R_2: S_2: $[+nas]_2$
    PM_1: M_1: $[-son]_1$ PM_2: M_2: $[+son]_2$
       $[-cont]_1$ $[-cont]_2$
     P_1: COR_1: $[+ant]_1$ P_2:   LABIAL$_2$

  C_1 C_2 Output: [bm]

  R_1: S_1: $[-nas]_1$ R_2: S_2: $[+nas]_2$
    PM_1: M_1: $[-son]_1$ PM_2: M_2: $[+son]_2$
       $[-cont]_1$ $[-cont]_2$
        P_{12}:   LABIAL$_{12}$

b. C_1 C_2 Input: /bn/

  R_1: S_1: $[-nas]_1$ R_2: S_2: $[+nas]_2$
    PM_1: M_1: $[-son]_1$ PM_2: M_2: $[+son]_2$
       $[-cont]_1$ $[-cont]_2$
     P_1:   LABIAL$_1$ P_2: COR_2: $[+ant]_2$

  C_1 C_2 Output: [bm]

  R_1: S_1: $[-nas]_1$ R_2: S_2: $[+nas]_2$
    PM_1: M_1: $[-son]_1$ PM_2: M_2: $[+son]_2$
       $[-cont]_1$ $[-cont]_2$
     P_{12}:   LABIAL$_{12}$

A curious aspect of these derivations is that the outputs are phonologically distinct, though phonetically identical: each output 'remembers' the segment that triggered the assimilation. To my knowledge, such global distinctions are not referred to by phonological rules, and a theory that allows them needs revision.

The difficulty arises from the fact that a coindexation theory provides two mechanisms to indicate when one node dominates another: grouping within the feature tree, and coindexing. We can solve the problem by restricting ourselves to just one definition of domination:

(60) Let B be a node in the feature tree forming a subset node of A. A
    DOMINATES B iff A and B share an index.

Under this definition, the putatively distinct outputs in (59) are notational variants. That is, while we may arrange nodes in outline form for convenience, only the indexing is formally significant.

Two technical revisions are necessitated by this proposal. In the Percolation Convention (21), 'dominated' must be understood to mean 'dominated before the indices were changed', so that deletions of indices

can be carried down the tree, as in (47e). Further, floating nodes (nodes not linked to prosodic structure) must bear 'place-holder' indices to show that they are units. When a floating node is linked to a prosodic position, its index is changed to that of the prosodic position.

9.5 Inalterability

Schein & Steriade (1984, 1986) and Hayes (1986) propose formal accounts of the phenomenon of 'inalterability', the blockage of phonological rules when applied to long segments. Since diphthongisation characteristically applies to long segments only, one wonders how it is compatible with inalterability constraints.

In fact, on close inspection none of the diphthongisation rules in this article threaten inalterability theory. Different theories are compatible with the data for different reasons.

Under the theory of Hayes (1986), inalterability is attributed to a Linking Constraint:

(61)   *Linking Constraint*
        Association lines [translation: indices] in structural descriptions
        are interpreted as exhaustive

The Linking Constraint makes the following predictions: rules formulated with single linkages to the prosodic tier apply to short segments only; rules formulated with double linkages apply to long segments only; and rules formulated on the segmental tier alone may apply to both short and long segments. Since the diphthongisation rules discussed here are explicitly restricted to doubly-linked segments (only long vowels undergo them), they may apply without violating the Linking Constraint.

The theory of Schein & Steriade (1986) proposes that conditions imposed on any node linked to the target of a rule must be met by all nodes linked to the target. Here again, if we make suitable assumptions about how conditions are defined, the rules discussed above are compatible with the theory.

There is one area in which the coindexation proposal made here interacts with the Linking Constraint theory. Consider rules that are expressed solely on the segmental tier, and thus are predicted to apply freely to both long and short segments. An example is found in Luganda (Clements 1986a), where /k g/ and /kk gg/ become [č ǰ] and [č: ǰ:] respectively before /i/ or the glide /j/. I formulate the rule as in (62):

(62)   *Luganda Palatalisation*

$$\begin{bmatrix} -\text{son} \\ -\text{cont} \end{bmatrix}_i \qquad [-\text{cons}]_j \qquad \text{Manner tier}$$

$$\text{DORSAL}_i \qquad\qquad\qquad \text{Dorsal tier}$$

$$\emptyset_j \qquad \text{Height tier}$$

Spread leftward: $[-\text{back}]_j$ [back] tier

This is interpreted as follows. (a) Structural description: a velar stop, indexed **i**, is followed by a high front vowel or glide, indexed **j**. (b) Structural change: the [−back] autosegment of the trigger (the vowel or glide) takes on the index of the target (the velar stop). This in effect spreads [−back] onto the velar stop, palatalising it.

The problem is that while this rule can convert /k g/ to [č ǰ], it cannot apply to /kk gg/: since the autosegments [−sonorant, −continuant] and Dorsal in the rule are singly indexed, by the Linking Constraint they cannot be matched up with the corresponding doubly-indexed auto-segments of a long /kk/ or /gg/. Thus it would seem that under the coindexation proposal, inalterability is wrongly predicted to occur even for segmental-tier-only rules.

This technical problem has a straightforward technical solution. Consider how we are to interpret variables like **i** in rules. While I have tacitly assumed that they stand for indices, a better alternative is to let them stand for sets of indices. That is, a variable like **i** may be matched against more than one index in a rule, provided that it is matched with the same set of indices throughout. A multiple indexation like **ij** (cf. (46), Lund Swedish Delabialisation) matches with the union of the sets of indices matched to **i** and **j**.

This proposal replicates the predictions of the original Linking Constraint, as follows:

(a) In segmental-tier-only rules like Luganda Palatalisation, the variable **i** may be interpreted either as a set of two indices, and thus match with doubly-linked /kk gg/; or a set having just one index, and thus match with singly-linked /k g/. The instruction 'Spread leftward' is interpreted as reassigning the appropriate number of indices in either case.

(b) Ordinary cases of inalterability involve rules that mention both segmental and prosodic tiers, but are not explicitly formulated to apply only to long segments. A schematic example of this class appears under (63):

(63) a. Rule: V_1 b. Form: V_1 V_2

           $[+F]_1$ $[+F]_{12}$

Under the Linking Constraint, (63a) cannot apply to (63b). To match the indexing of [+F] exhaustively, we would have to set $i = \{1, 2\}$. But when we do this, the Linking Constraint blocks the rule, since neither V position is indexed $\{1, 2\}$.

(c) In a long-segments-only rule like (46), **ij** is matched on the segmental tier, while **i** and **j** are matched individually on the prosodic tier, so the rule may apply.
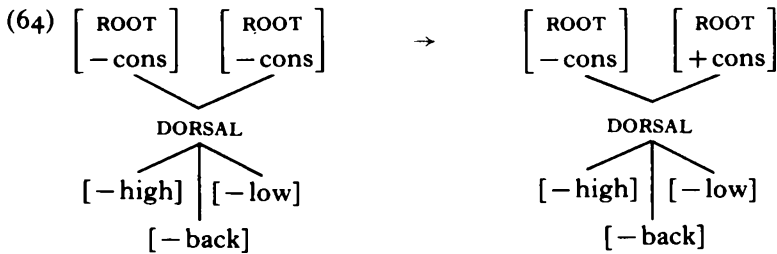
The upshot is that, suitably interpreted, the coindexation theory is compatible with a version of the Linking Constraint that makes the same predictions as before. In general, I believe that the issue of inalterability and how to account for it is largely independent of how we construe the structure of multitiered representations.
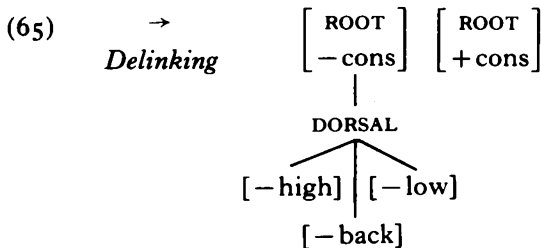
10 Two-root length

Selkirk (1988) proposes an alternative theory of phonological length, presented in part as an answer to the Diphthongisation Paradox. Under this theory, long segments have two Root nodes, to which the Nasal tier, the Laryngeal tier, and (in vowels) the individual articulator tiers are directly linked. Root nodes bear manner features, and are dominated by a moraic prosodic tier.

Selkirk's theory raises a number of issues that go beyond the scope of this article. Here, I will discuss only her approach to diphthongisation. For diphthongisation of the Laryngeal and Nasal tiers, which are linked to the Root, Selkirk's analysis is the same as in Steriade (1987b), discussed in §4. For vowel diphthongisation, Selkirk suggests a mechanism I will now describe, using her example /eː/ → [ei].
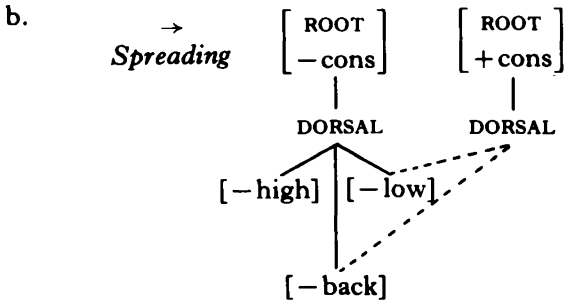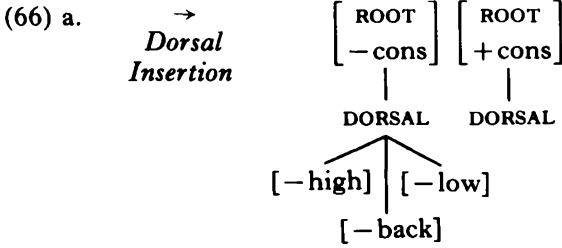
(a) The second Root node of /eː/ is marked [+consonantal]:

(64)
$$
\begin{bmatrix} \text{ROOT} \\ -\text{cons} \end{bmatrix} \quad \begin{bmatrix} \text{ROOT} \\ -\text{cons} \end{bmatrix} \qquad \rightarrow \qquad \begin{bmatrix} \text{ROOT} \\ -\text{cons} \end{bmatrix} \quad \begin{bmatrix} \text{ROOT} \\ +\text{cons} \end{bmatrix}
$$

$$
\begin{array}{ccc}
\text{DORSAL} & & \text{DORSAL} \\
[-\text{high}] \ [-\text{low}] & & [-\text{high}] \ [-\text{low}] \\
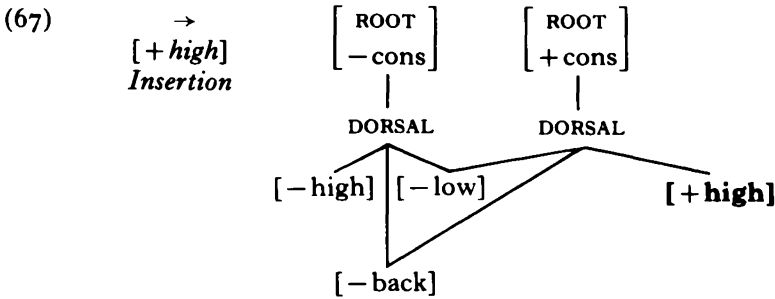[-\text{back}] & & [-\text{back}]
\end{array}
$$

(b) Under a general principle of Dependent Linking, motivated elsewhere, daughter nodes are allowed to form double linkages only to identical Root nodes. This forces the Dorsal node to delink from one of the two Roots, determined language-specifically. Here, Dorsal delinks from the second Root of /eː/:

(65)   →
     Delinking $\begin{bmatrix} \text{ROOT} \\ -\text{cons} \end{bmatrix} \quad \begin{bmatrix} \text{ROOT} \\ +\text{cons} \end{bmatrix}$

$$
\begin{array}{c}
\text{DORSAL} \\
[-\text{high}] \ [-\text{low}] \\
[-\text{back}]
\end{array}
$$

(c) A new Dorsal node is filled in under the vacated second Root. Then all features that do *not* diphthongise (here, [back] and [low]) are filled in by a rule of spreading:

(66) a.

→
Dorsal
Insertion

$$\begin{bmatrix} \text{ROOT} \\ -\text{cons} \end{bmatrix} \begin{bmatrix} \text{ROOT} \\ +\text{cons} \end{bmatrix}$$

DORSAL   DORSAL

[−high] [−low]

[−back]

b.

→
Spreading

$$\begin{bmatrix} \text{ROOT} \\ -\text{cons} \end{bmatrix} \begin{bmatrix} \text{ROOT} \\ +\text{cons} \end{bmatrix}$$

DORSAL   DORSAL

[−high] [−low]

[−back]

(d) Those vowel features that *do* diphthongise (here, [high]) are assigned the opposite value to avoid an OCP violation. This derives [ei]:

(67)

→
[+*high*]
Insertion

$$\begin{bmatrix} \text{ROOT} \\ -\text{cons} \end{bmatrix} \begin{bmatrix} \text{ROOT} \\ +\text{cons} \end{bmatrix}$$

DORSAL   DORSAL

[−high] [−low]   **[+high]**

[−back]

There are several drawbacks to this account. First, it is not generally the case that the less sonorous mora of a derived diphthong is [+consonantal]. The less sonorous mora is often a mid vowel (cf. §§8.2–8.4), which could hardly be [+consonantal] by any ordinary definition. Further, the evidence from Flapping (Kahn 1976: 56–58) clearly shows that the diphthongs of English end in a [−consonantal] segment.

Second, under Selkirk's theory, many rules of diphthongisation must be expressed as non-constituent spreading, thus weakening the explanatory force of feature tree theory. For example, in (66b) the diphthongisation rule must spread the non-constituent feature set {[low], [back]}. In general, under Selkirk's approach rules of diphthongisation must spread the set of non-diphthongising features, which will usually be rather arbitrary. The problem becomes worse when we consider that by the

Dependent Linking principle, *all* the daughters of the altered Root node will be delinked, and all of them will have to recover their old feature values through spreading.

Third, the approach of spreading all the non-diphthongising features predicts outcomes that appear not to arise. Since direction of spreading is known to be a language-specific property, we might expect rules of diphthongisation in which different features were filled in from opposite directions: for example, /juː/ → [jøu], where the inserted Dorsal node receives [−back] from the preceding /j/ and [+round] from the following /u/. To my knowledge, this never happens. Rather, the inserted Dorsal node always gets its fill-in values from the Dorsal node of the other half of the diphthong – that is, the altered half of the diphthong gets back all the feature values it used to have, other than the diphthongising feature(s). This generalisation is an accident under Selkirk's theory.

The advantage of the coindexation theory proposed here is that diphthongisation rules apply only to the altered feature or node; all else remains the same. We need not posit complex adjustments of tree geometry, nor do we have to mark vowels as [+consonantal]. A coindexation theory does not use spreading to restore the values of unaltered features, so we need not invoke non-constituent spreading, and we also avoid predicting cases like /juː/ → /jøu/. In short, under the coindexation proposal, diphthongisation rules do nothing but diphthongise. *A priori*, this seems the right approach to take.

[1] Clements attributes the basic idea he develops to unpublished work by Mohanan (1983) and Mascaró (1983).

[2] Steriade assigns [nasal] and the manner features to other locations in the tree; hence for purposes of this section Place and Supralaryngeal are equivalent terms.

[3] These diphthongisations are limited to stressed open syllables, which are most reasonably interpreted as positions of lengthening (cf. Otero 1988).

[4] Linkages are not in general inherited upward, even in Clements' original theory: if they were, then whenever a node N below the level of the Root underwent spreading, all nodes dominating N would also spread in the same way. This is obviously not true, since partial assimilation exists.

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