Consonant Gradation as a Prosodic Constraint on Aperture Nodes

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1. Introduction

Consonant gradation (henceforth CG), also called consonant mutation or lenition, has been a long-standing problem in phonology. Alternations under CG "weaken" initial consonants, by voicing, spirantizing, gliding, or deleting them. Often, CG appears to be syntactically, morphosyntactically, or lexically conditioned. The purpose of this paper is to present a formal characterization of "weakening". The data considered in this paper are from Mende, a SW Mande language spoken in Sierra Leone, and Welsh (Celtic).

Examples of CG in Mende and Welsh are given in (1) below. The first column gives the phonetic CG alternations, the second and third columns give the nonmutated and mutated forms, respectively, in orthographic form.

(1a) Mende (from Conteh, Cowper and Rice 1985):

p	→	w	pa 'coming'	wa! 'come!'
t	→	l	tei 'the chicken'	nya lei 'my chicken'
k	→	g	kulo 'in front of'	bi gulo 'in front of you (sg.)'
kp	→	gb	kpekei 'the razor'	nya gbekei 'my razor'
s	→	j	sembe 'big'	ngila jembei na 'that big dog'
mb	→	b	mbu 'under'	ndendei bu 'in the shade'
nd	→	l	ndeindei 'boat'	fefe lendei 'sailboat' (fefe 'wind')
ng	→	y	ngombu-i 'the fire'	nya yombu-i 'my fire'
ng	→	w	ngole-i 'the sobbing'	nya wole-i 'my sobbing'

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(1b) Welsh lenition[1]

p	→	b	pen 'head'	ei ben 'his head'
t	→	d	tad 'father'	ei dad 'his father'
k	→	g	ceffyl 'horse'	ei geffyl 'his horse'
b	→	v	basged 'basket'	ei fasged 'his basket'
d	→	ð	desg 'desk'	ei ddesg 'his desk'
g	→	0	gardd 'garden'	ei ardd 'his garden'
m	→	v	mam 'mother'	ei fam 'his mother'
ɬ	→	l	llong 'ship'	ei long 'his ship'
r^h	→	r	rhosyn 'rose'	ei rosyn 'his rose'

Past approaches have tried to represent the alternations in (1), and CG in other languages, as the insertion of some feature or set of features, such as [+cont], [+son], or [+voice] (e.g. Lieber (1983, 1984, 1985) for Fula, Nuer, Welsh, and Mende, among others; Swingle (1992) for Irish). CG is notoriously difficult to account for as feature insertion, however, because the mutated segments in a given language often do not have any features in common on the surface. Within one and the same language, CG may involve voicing of some consonants, while other consonants denasalize, spirantize, or delete. Notice that, in Welsh, the voiceless stops alternate with voiced stops, while the bilabial nasal stop turns into a continuant. Similarly, in Mende, velar voiceless stops alternate with voiced stops, while other stops alternate with continuants.

One way to account for the fact that mutated segments do not form natural classes on the surface is to assume prespecification of certain features in the underlying form. This is the strategy proposed, e.g. in Lieber (1983). On Lieber's analysis, segments that are subject to CG are underspecified for certain features. The 'missing' features are then provided by a floating autosegment. Segments that do not receive all of the features provided by CG or that do not participate in CG at all, are prespecified for some or all of the mutation features.

Prespecification might indeed be a promising solution to the problem just mentioned, if it were the case that underlyingly specified features always took precedence over features provided by CG. The fact is, however, that CG can change underlying feature specifications. For instance, in Mende, the prenasalized stops lose their [+nasal] feature under CG.

CG alternations often result in sonority increases, and it might be tempting to interpret the notion of "weakening" – and of "strengthening" as promotion and demotion, respectively, on a sonority scale, perhaps along the lines of, e.g. Foley (1970), Vennemann (1972), or Selkirk (1984). Not all CG effects involve sonority increases, however, and furthermore, not all segments in the inventory of a given language even participate in CG alternations at all. For instance, the mutation of Welsh /m/ to /v/ results in a sonority decrease; and the alveolar nasal /n/, although equal in sonority to /m/, does not mutate at all.

The proposal to be presented in this paper is that CG can be formalized as a constraint on segment complexity. The proposal draws upon Steriade's theory of closure and release (Steriade (1993, forthcoming); a similar proposal is being pursued in Grijzenhout (in preparation)). Roughly speaking, CG amounts to a constraint on segment

[1]Welsh, like the other Celtic languages, displays a number of different initial consonant mutations. The one that will concern us here is the one traditionally referred to as 'lenition' or 'soft mutation'.

complexity. CG limits a given segment to at most one aperture node, and it forces certain features to remain unparsed. A schematic example is given in (2):

(2) Reduction of an Aspirated Stop to One Aperture Position

A_0 A_+ | | Pl [asp]	→ A_0 $<A_+>$ | Pl <asp>	A_0 A_+ | | Pl [asp]	→ $<A_0>$ A_+ / Pl <asp>
a voiceless stop	a voiced stop	a voiceless stop	an approximant

Both phenomena – the loss of one aperture position and of certain features - can be unified as the effect of an Alignment constraint (cf. McCarthy & Prince 1993), aligning the left edge of a stem with a vowel place feature. The precise effect on a given type of segment of being in the mutation environment is determined by other, independent constraints, in particular, by the PARSE constraint, and by the underlying form of the segment.

This approach further allows a characterization of the behavior of nonmutating segments, i.e segments that do not undergo any changes when they occur in CG environments. Nonmutating segments are those that in their underlying form already conform to the mutation constraint, or violate it minimally, or whose compliance with the constraint requires fatal PARSE violations.

2. Theoretical Prerequisites

The analysis of CG presented in this paper draws upon Steriade's theory of closure and release (Steriade 1993, forthcoming). In this model, what would be the root node of a segment in other approaches is a so-called aperture node (A-node) or aperture position, marked for degree of closure. There are two types of A-nodes, A_0 for complete closure, and A_+ for partial closure.[2] Sample representations of Welsh and Mende stops are given in (3):

(3) Mende and Welsh [p], [b], [t], [d] (surface forms)

[p]:	A_0 A_+ | \\ [lab] [asp]	[b]	A_0 | [lab]	[t]	A_0 A_+ | \\ [cor] [asp]	[d]	A_0 | [cor]

Notice first that the voicing distinction in the stops is reflected here as presence or absence of aspiration. In both languages, voiceless stops are phonetically aspirated (cf. e.g. Ball 1984). As shown in (3), an aspirated stop consists of an A_0 node dominating the Place features[3], followed by an A_+ node dominating the feature [asp]. An unaspirated stop, by contrast, does not have any features on the release. Approximants and fricatives have only one A-node, marked A_+. For details concerning the theory of closure and release, the reader is referred to Steriade's own work (see references).

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[2] Readers familiar with Steriade's work will notice that the representations employed in this paper differ slightly from Steriade's original proposal. In Steriade (1993, forthcoming), there are three types of A-nodes, A_0 for complete closure, A_{fric} for partial closure with audible friction, and A_{max} for maximal aperture as in the production of an approximant.

[3] Notice that my proposal does not depend on any particular assumptions about feature geometry. E.g., for the analysis presented here, it is not necessary to assume the existence of organizing nodes, such as the Place node. It is sufficient to assume that the PARSE constraints can refer to place features as a class (see Padgett 1995).

The charts in the appendix show the underlying representations of all segments from the inventories of Welsh and Mende. The criteria used here for determining underlying forms are consistent with those established in Inkelas (this volume), in that any nonalternating aspects of segment structure are prespecified in underlying representation. Specifically, dominance relations between A-nodes and features are assumed to be prespecified if they are not subject to alternations. Furthermore, any material present in any surface form of a given segment must be present in UR, so as to avoid any FILL violations arising through insertion of features or A-nodes.

3. The analysis

3.1 The mutation of voiceless stops in Mende

The analysis to be presented here will be implemented in the framework of Optimality Theory (Prince & Smolensky 1993). Since constraints in OT are violable, this framework allows us characterize CG as the effect of a unitary set of constraints, even though not all mutated segments have any features in common on the surface. The constraints that will be considered are as follows:

ONS >> PreservePath >> AlignL (stem, VPl) >> PARSE, PARSE A, PARSE PL, PARSE A+.

The highest ranked constraint, unviolated by any successful candidates, is the ONSET constraint, which requires every syllables to have an onset. Next in the hierarchy is a constraint I am calling PreservePath. This constraint bans any delinking of underlying association lines, ensuring that alternations will be structure-filling, rather than structure-changing.

The constraint responsible for the CG alternations is an alignment constraint AlignL (stem, VPl), forcing the left edge of a morphological stem to coincide with a vowel place feature. Since AlignL is dominated by ONSET in both languages considered here, candidates that perfectly comply with AlignL generally fail because their first syllable will lack an onset. (The only exception to this are the glides, which consist of vowel place features syllabified into the syllable onset.)

All of the remaining constraints are more or less specific PARSE constraints, unranked with respect to one another. This family of constraints encode markedness in the manner proposed in Kiparsky (1994). Thus, we find PARSE A, a general constraint requiring A-nodes to be parsed, alongside PARSE A+, which requires the marked structure A+ to be parsed.

Tableau 1 shows the effect of these constraints on Mende /p/. The input contains a consonantal place feature and the feature [asp], an A_0 and an A_+. Candidate a. preserves all underlying material, thereby satisfying ONSET, as well PARSE, but causing multiple violations of the AlignL. Candidate b. satisfies AlignL but incurs a fatal violation of ONSET by leaving the entire segment unparsed.

Candidate c. fails because it violates Parse Place. Candidates d. and e. each parse one A-node along with the place feature. The winner is e., since it preserves the unmarked A_+ node.

One further comment on tableau 1 and all following tableaux may be in order: the tableaux show the effect of the constraints on a given segment in stem-initial position, i.e. followed by a vowel. A more complete version of the tableaux would show not just the stem-initial segment, but rather the whole stem. In all examples considered here, the segment immediately following the stem-initial consonant will be a vowel.

Tableau 1: Mende p → w

	/p/	Input: A_0 A_+ Pl [asp]	ONS	PrePath	AlignL	PARSE	Parse A	Parse Place	Parse A_+
a.	[p]	A_0 A_+ | | Pl [asp]			****![4] A_0, A_+, Pl, asp				
b.	0	<A_0,A_+, Pl, [asp]>	*!			****	**	*	*
c.	[h]	A_+ <A_0,Pl> | [asp]			** A_+, asp[5]	**	*	*!	
d.	[b]	A_0 <A_+,asp> | Pl			** A_0, Pl	**	*		*!
e.☞	[w]	A_+ <A_0,asp> | Pl			** A_+, Pl	**	*		

The mutation of /t/, which alternates with [l], i.e. the homorganic continuant, exactly parallels that of /p/ shown in tableau 1, the only difference lying of course in the place feature.

3.2 The underlying forms of Welsh oral stops

The assumptions made here for determining underlying forms are that, generally speaking, material found in any surface forms of a given segment is present underlyingly. That is to say, satisfaction of the constraint AlignL is never achieved through insertion of features or A-positions, which would result in violations of FILL. Secondly, dominance relations between A-nodes and features are prespecified if they are not subject to alternations. Applying these criteria, we derive the URs shown in (4) for Mende /p/, Welsh /p/ and Welsh /b/.

(4) Bilabial stops (underlying representations)

A_0 A_+ [lab] [asp] **Mende /p/**	A_0 A_+ | | [lab] [asp] **Welsh /p/**	A_0 A_+ [lab] **Welsh /b/**

Recall that the place feature of Mende /p/ is dominated by the A_0 node in the nonmutated form, and by the A+ node in the mutated form. Accordingly, no association lines are specified in the underlying representation of this segment. By contrast, Welsh /p/ alternates with [b], i.e. a stop, not a continuant. Thus, the place feature is dominated by the

[4] For convenience, the structures causing violations of AlignL are listed in the tableaux.

[5] The fact that candidates c.-e. incur two violations of AlignL raises the question as to how violations of Align are computed. This question is part of a larger issue which we will turn to in section 5.

A_0 node in all surface forms of this segment. The association line ("path", or "dominance relation") between the A_0 node and the place feature is therefore prespecified in UR.

Finally, we turn to the case of Welsh /b/. Recall that [b] alternates with [v] in Welsh. Since the mutated form is a continuant, requiring an A_+ node, while the nonmutated form is a stop, requiring an A_0 node, both nodes are present in the underlying form. As in the case of Mende /p/, the place features are not linked to either of the A-nodes in the input, leaving the place features free to associate to either A-position.

3.3 The mutation of Welsh oral stops

We are now in a position to compare the mutation of the bilabial stops in Welsh, shown in tableaux 2 and 3, with that of the voiceless bilabial stop in Mende, which was shown in tableau 1 above. As the following tableaux show, subjecting the forms discussed in the preceding section to the set of constraints correctly derives [b] as the mutated form of Welsh /p/, and [v] as the mutated form of Welsh /b/.

Tableau 2: Welsh p → b

	/p/	Input: A_0 A_+ | | Pl [asp]	ONS	PrePath	Align L	PARSE	Parse A	Parse Place	Parse A_+
a.	[p]	A_0 A_+ | | Pl [asp]			****! A_0,A_+, Pl,asp				
b.☞	[b]	A_0 <A_+,asp> | Pl			** **A_0,Pl**	**	*		*
c.	[v]	A_+ <A_0,asp> | Pl		**!	** **A_+,Pl**	**	*		

The crucial difference between tableau 1 and tableau 2 concerns the underlying linking of the Place features to the A-positions. In tableau 1, the winning candidate was the one that satisfied PARSE A_+. The constraint PreservePath did not come into play at all, since the path from A-nodes to features was not specified underlyingly. In tableau 2, by contrast, the place feature is linked to the A_0 node in the input. Preserving the A_+ node, as candidate c. does, now comes at the cost of delinking the place node from its position in the input, causing a fatal violation of PreservePath.

Tableau 3 shows the effects of the set of constraints considered here on the underlying form of Welsh /b/.

Tableau 3: Welsh b → v

	/b/	Input: A_0 A_+ Pl	ONS	PrePath	AlignL	PARSE	Parse A	Parse Place	Parse A_+
a.	[b]	A_0 $\langle A_+ \rangle$ / Pl			** A_0,Pl	*	*		*!
b.☞	[v]	A_+ $\langle A_0 \rangle$ / Pl			** A_+,Pl	*	*		

The alternations of the other oral stops are analogous, except for the case of Welsh /g/. The predicted form of this segment under mutation, given the assumptions made so far, is a velar continuant. Although historically this was indeed the mutated reflex of /g/, (see Morris-Jones 1913), synchronically, this segment deletes under mutation. I am led to assume, following Ball & Müller (1992) and Lieber (1986), among others, that the output of the constraints responsible for mutation is indeed a velar continuant, and that this segment deletes at a separate stage. Specifically, I assume a segment structure constraint that outranks Parse Place.[6]

3.4 The mutation of continuants

In all segments considered so far, the nonmutated form had two A-positions while the mutated form preserved only one A-node. The Alignment constraint forced one A-node, as well as the feature [asp], to remain unparsed. In the case of continuants, to which we now turn, the input contains only one A-node. The Alignment constraint can only have an effect on features, not A-nodes, since unparsing of the only A-node in the onset would result in ONSET violations.

Consider first tableau 4, which shows the mutation of the Welsh liquids. The main point to notice here is that parsing [asp] is not crucial for deriving a well-formed output segment, and that, as a consequence, the feature is not parsed.

[6] A more satisfying alternative might be to recognize that not all Place features are treated uniformly by the PARSE constraint. That is to say, PARSE [vel] needs to be ranked lower than the other PARSE PLACE constraints.

Tableau 4: Welsh ɬ -> l ; r^h -> r

	/ɬ/	Input: A_+[7] | Pl [asp]	ONS	PrePath	AlignL	PARSE	Parse A	Parse Place	Parse A_+
a.	[ɬ]	A_+ | \\ Pl [asp]			***! A_+,Pl, asp				
b.	h	A_+ <Pl > | [asp]		*!	** **A_+,asp**	*		*	
c.☞	[l]	A_+ <asp> | Pl			** A_+,Pl	*			

3.5 The mutation of nasals and prenasalized segments:

Tableau 5 shows the mutation of the prenasalized coronal stop in Mende. The mutation of Welsh /m/ essentially parallels this case. For the underlying forms of the remaining nasals, the reader is referred to chart given in the appendix. The manner in which the constraints considered here apply to these segments will be clear at this point.

Tableau 5: Mende nd → l

	/nd/	Input: A_0 A_+ [nas] Pl	ONS	PrePath	AlignL	PARSE	Parse A	Parse Place	Parse A_+
a.	[nl]	A_0 A_+ | | [nas] Pl			****! A_0,A_+, nas, Pl				
b.	[n]	A_0 <A_+> / \\ [nas] Pl			***! A_0,nas, Pl	*			*
c.	[l̃]	A_+ <A_0> / \\ [nas] Pl			***! A_+,nas, Pl	*			
d.☞	[l]	A_+ <A_0,nas> | Pl			** A_+,Pl	**	*		

The application of the constraints in this tableau requires no further comment. One segment that does need further discussion, however, is the prenasalized velar stop in Mende.

[7] For reasons of space, the input in tableau 4 does not show the feature [son], which is also present in the underlying form of the liquids (cf. the chart in the appendix).

In the summary of alternations in (2a) above, two mutated forms were given for the prenasalized velar stop. For convenience, the relevant examples are repeated in (5) below:

(5)	ng → y	ngombu-i 'the fire'	nya yombu-i 'my fire'
	ng → w	ngole-i 'the sobbing'	nya wole-i 'my sobbing'

In the first example, the mutated form is a palatal glide, while in the second example it is a labiovelar. The environments in which we find these two forms are partially overlapping (cf. Dwyer 1974). Two distinct underlying forms have to be assumed, therefore, which differ in their secondary place features. (This is also the analysis adopted in Tateishi (1988), among others). Of special interest to the present discussion is the fact that the preservation of the secondary (V-place) features in the mutated form over the consonantal place features follows from the alignment constraint without further stipulation, as shown in tableau 6 below.

Tableau 6: Mende ŋg → w

	/ŋg/	Input: A_0 A_+ / \ [nas] CPl VPl	ONS	PrePath	AlignL	PARSE	Parse A	Parse Place	Parse A_+
a.	[ŋg^w]	A_0 A_+ / \ \ [nas] CPl VPl			***! A_0,nas, CPl				
b.	[ŋ]	A_0 <A_+,VPl> / \ [nas] CPl			***! A_0,nas, CPl	**	*	*	*
c.	[g]	A_0 <A_+,VPl, | nas> CPl		*!	*** **A_0,CPl**	***	*	*	*
d.☞	[w]	A_+ <A_0,nas, | CPl> VPl				***	*	*	
e.	[ɣ]	A_+ <A_0,VPl, | nas> CPl		*!	** A_+,CPl	***	*	*	

3.6 The mutation of affricates in Welsh

Finally, we turn to the mutation of affricates in Welsh. These segments only occur in English borrowings, but participate in the mutation system (see Griffen 1974, Jones 1984). In such forms, the voiceless affricate alternates with the voiced affricate. The derivation is shown in tableau 7.

Tableau 7: Welsh /tʃ/→/dʒ/

	/tʃ/	Input: A_0 A_+ | / Pl [c.gl.]	ONS	PrePath	AlignL	PARSE	Parse A	Parse Place	Parse A_+
a.	[tʃ]	A_0 A_+ |/ | Pl [asp]			****! A_0,A_+, Pl, asp				
b.	[d]	A_0 <A_+, | c.gl> Pl		*!	****** **A_0,Pl**	**	*	*!	
c.☞	[dʒ]	A_0 A_+ <c.gl.> | / Pl			******* **A_0,A_+, Pl**	*			

The mutation of the remaining Welsh and Mende segments requires no additional comment, given the underlying forms in the appendix, and the constraints in tableaux 1-7.

4. Nonmutating segments

In the preceding sections, we saw that CG can be formalized as an alignment constraint, applying in conjunction with ONSET and PARSE. An analysis of CG is not complete unless it also addresses the fact that not all segments in the inventory of a given language undergo any changes in the CG environments. The nonmutating segments of Welsh and Mende are listed in (6). Segments that are not themselves possible mutated forms are in bold face.

(6) Nonmutating segments

(a) Mende		(b) Welsh	
oral stops:	b,**d**,g,gb	nasals:	**n**,(**ŋ**)[8]
nasals:	**m**,**n**,**ny**,**ŋ**	fricatives:	f,θ,s,x,v,ð
fricatives, glides, liquids:	v,j,y,w,l,**h**	liquids:	l,r

In tableaux 1-7 above, we saw that any changes to underlying representations generally result in PARSE (or FILL) violations. Nonmutating segmetns are segments whose underlying forms already optimally conform with the constraints. For example, voiced stops and approximants in Mende consist solely in an A-position and place features. Failure to parse either the A-node or the place features results in fatal underparsing.

The underlying forms of all other nonmutating segments are likewise fully specified. Delinking any features present (and pre-attached) in the underlying forms results in violations of PreservePath, which also outranks AlignL. Under this approach, it is possible to model the behavior of nonmutating segmetns without resorting to ad hoc devices such as negative rule features.

[8] Since ŋ does not occur in onset position, the fact that it does not undergo CG requires no further explanation.

5. Further discussion: AlignL (stem, VPl), PreservePath

The analysis proposed here, in particular the constraint AlignL (stem, VPl), raises a number of questions.

One question concerns the reference to a morphological category in the alignment constraint. It is certainly possible to reformulate the constraint as AlignL (PrWd,VPl). It should be pointed out, however, that CG, at least in the two languages considered here, might indeed be a good case for morpheme-specific alignment constraints, since in both languages CG is subject to lexical exceptions.

A question with more far-reaching consequences is how violations of an alignment constraint that refers to elements on different prosodic levels – A-positions and features – are to be computed. This question is part of a larger issue which is also raised in similar form in Itô & Mester (1994). The implications of this problem go beyond the scope of this paper, but we will now briefly turn to a possible alternative analysis which avoids the problems just mentioned while retaining the main insight of the analysis presented in the preceding sections.

In essence, the effect of the alignment constraint is to force consonants in stem-initial position to parse as little structure – A-positions and features – as possible. It will be noted that the set of constraints *STRUC would have the same effect (see Prince & Smolensky (1993) and McCarthy & Prince (1993) for discussion). There are two facts that the *STRUC constraint, taken by itself, does not capture, but that could still be derived by other constraints applying in conjunction with *STRUC.

The first is the fact that CG occurs at constituent edges. The alignment constraint, but not the *STRUC constraint, encodes this fact directly. Other accounts for why CG occurs at edges are possible, however. One such explanation, might take into account adjacency relations between input elements are generally preserved in the output.[9] Since unparsing of elements at edges does not affect adjacency relations within a given constituent, segments at constituent edges can fail to be parsed, satisfying *STRUC, without altering adjacency relations.

The second fact which the *STRUC constraint does not capture without additional assumptions is that secondary place features are parsed more freely than any other features in CG. The alignment constrain captured this because VPl features, unlike all other features, in stem initial position satisfy AlignL (stem, VPl).

While the *STRUC constraint itself does not express this asymmetry, it can still produce the correct output if we assume ranked PARSE constraints. The constraint hierachy in (7) would then replace the set of constraints considered so far:

(7) PrePath,HavePlace >> PARSE VPl >> *STRUC >> PARSE CPl >> PARSE asp >> (...)

More generally, the set of constraints shown in (8) characterizes CG:

(8) PARSE [x] >> *STRUC >> PARSE[y]

where x and y will vary from language to language.

[9] This idea was suggested to me by Sharon Inkelas.

It remains to be seen whether the ranking of PARSE [x] and PARSE [y] follows from general markedness considerations, such as markednes or articulatory effort. This issue is discussed further in Gahl (forthcoming).

6. Conclusion

We have seen that CG can be modeled as the effect of an alignment constraint. Although many of the assumptions presented in this paper require further discussion and justification, this approach has several advantages over past analyses of CG. As a tool for the cross-linguistic investigation of CG, it allows a simple, general characterization of CG as a constraint on segment complexity, while relegating the cross-linguistic differences in CG phenomena to other, independent aspects of particular grammars.

A more general point that this analysis highlights is that identical sets of constraints have different effects on phonetically similar segments in different languages. While work in underspecification theory has often relied on the assumption that phonological representations may be different for different inventories, the consequences of this within the framework of OT, i.e. a framework in which constraints are universal, have not been fully exploited.

Appendix: inventories

The following charts show underlying forms of Mende and Welsh inventories, using feature matrices in Tateishi (1987, 88) for Mende, and Ball & Müller (1992), citing Sproat (1986) for Welsh.

(a) Mende

<table>
<tr><td>voiceless stops</td><td>A_0 A_+
[lab] [asp]
[p]</td><td>A_0 A_+
[cor] [asp]
[t]</td><td>A_0 A_+
| \
[vel] [asp]
[k]</td><td>A_0 A_+
/\ \
[lab][vel] [asp]
[kp]</td></tr>
<tr><td>voiced stops</td><td>A_0
|
[lab]
[b]</td><td>A_0
|
[cor]
[d]</td><td>A_0
|
[vel]
[g]</td><td>A_0
/ \
[lab] [vel]
[gb]</td></tr>
<tr><td>prenasalized stops</td><td>A_0 A_+[10]
| \
[nas] [lab]
[mb]</td><td>A_0 A_+
|
[nas] [cor]
[nd]</td><td>A_0 A_+
|
[nas] [high]
[nj]</td><td>A_0 A_+
/
[nas] [vel],VPl
[ng]</td></tr>
<tr><td>plain nasals</td><td>A_0
/ \
[nas] [lab]
[m]</td><td>A_0
/ \
[nas] [cor]
[n]</td><td>A_0
/ \
[nas] [high]
[ny]</td><td>A_0
/ \
[nas][vel]
[ŋ]</td></tr>
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| \
[c.gl][strd][lab]
[f]</td><td>A_+
/ \
[strid] [lab]
[v]</td><td>A_+
/ \
[strid][cor]
[j]</td><td>A_+
/ \
[strid][cor]
[j]</td></tr>
<tr><td>approximants</td><td>A_+
|
[lab]
[w]</td><td>A_+
|
[cor]
[l]</td><td>A_+
|
[high]
[y]</td><td>A_+
|
[asp]
[h]</td></tr>
</table>

(b) Welsh:

<table>
<tr><td>stops</td><td>A_0 A_+
| \
[lab] [asp]
[p]</td><td>A_0
|
[lab]
[b]</td><td>A_0 A_+
| \
[cor][asp]
[t]</td><td>A_0
|
[cor]
[d]</td><td>A_0 A_+
| \
[vel][asp]
[k]</td><td>A_0
|
[vel]
[g]</td></tr>
<tr><td>fric.</td><td>A_+
/ | \
[c.gl] strd Pl
[f]</td><td>A_+
/ \
strd Pl
[v]</td><td>A_+
/ \
[c.gl.] Pl
[θ]</td><td>A_+
|
[cor]
[ð]</td><td>A_+
/ \
[c.gl.]Pl
[x]</td><td>A_+
|
[s.gl.]
[h]</td></tr>
<tr><td></td><td></td><td></td><td>A_+
/ \
[c.gl.]Pl
[s]</td><td>A_+
|
Pl
[ß]</td><td></td><td></td></tr>
</table>

(continued on next page)

[10] The fact that /mb/ is a stop in both the mutated and the nonmutated form is reflected here in the association of the place feature to the A_0 node in underlying form. An alternative would be to represent this segment as having two A_0 nodes. Interestingly, the historical source of Mende /mb/ is a nasal preceding an implosive. By contrast, all other prenasalized stops in Mende go back to sequences of nasals + continuants (cf. Hyman 1974, Dwyer 1974).

(b) Welsh (continued):

liquids	A+ | Pl **[lh]**	A+ | Pl **[l]**	A+ | Pl **[rh]**	A+ | Pl **[r]**		
nasals	A_0 \\ [nas]][lab] **[m]**	A_0 / \\ [nas] [cor] **[n]**	A_0 / \\ [nas] [vel] **[ŋ]**			

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