The Laryngeal Specifications of Fricatives*

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Though laryngeal features have been a central concern of phonologists for the past 25 years (cf. Kim 1970, Halle and Stevens 1971, Thráinsson 1978, Iverson 1983, Keating 1984, Lombardi 1991, Blevins 1993, Kingston and Diehl 1994, Iverson and Salmons 1995), little attention has been given to the laryngeal specifications of fricatives. Halle and Stevens (1971) suggest that fricatives are generally [-spread glottis] (roughly equivalent to ‘ unaspirated’ in traditional terms), but can exceptionally be [+spread], as in Burmese. The same view is tacitly accepted by many phonologists and phoneticians (e.g. Maddieson (1984), Catford (1988)).

Recent phonetic work by among others Kingston (1990) and Stevens (1991) has suggested, however, that at least voiceless fricatives are generally produced with a spread glottis. According to Stevens, a voiceless fricative cannot be produced without spreading the glottis, because this glottal adjustment is necessary in order to build up sufficient pressure behind the constriction formed by the primary articulator for the fricative. Based on this observation, Halle 1995 proposes that all fricatives are [+spread]. Halle’s proposal also encounters a number of problems, however. It is difficult, for example, to distinguish Burmese plain $s$ from aspirated $s^h$, both of which must be [+spread] in his model. Halle’s generalization also fails to account for Catford’s observation that voiced obstruents are accompanied by a narrowing of the glottis (1977:112).

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In this paper I propose a system of laryngeal specifications that accounts for both the phonetic observations of Kingston, Stevens, and Catford, and the phonological behavior of fricatives in a number of languages with rich systems of laryngeal contrasts: the New Julfa dialect of Armenian, Pali, Sanskrit, Greek, and Thai. The phonological phenomena to be considered here strongly suggest that the unmarked specification for voiceless fricatives is [+spread], and the specification for voiced fricatives is [-spread].

1. Laryngeal Assimilation in Clusters

Our first set of evidence comes from the behavior of consonant clusters in the Armenian dialect of New Julfa (Vaux (forthcoming)), which is now spoken only by a few older Armenian natives of Isfahan. Like Sanskrit, this dialect has a four-way laryngeal contrast in its stop system, represented in (1).¹

(1) New Julfa consonant system

\[
\begin{array}{cccccccc}
  b & b^h & p & p^h & f & v & m \\
  d & d^h & t & t^h & s & z & n \\
  dz & dz^h & ts & ts^h & \\
  dʒ & dʒ^h & tf & tf^h & f & z \\
  g & g^h & k & k^h & \chi & \kappa & \\
  & & & & h & \breve{h} & \\
\end{array}
\]

\[j \quad r \quad \breve{r} \quad l \quad \lambda\]

1.1. The New Julfa future morpheme

New Julfa forms the future tense by adding the prefix \(k\)- to the present subjunctive. This \(k\)-surfaces as \(k\)- before vowels and plain voiceless consonants (2a), \(g\)- before plain voiced
consonants (2b), \( k^h \)- before voiceless aspirates and voiceless fricatives (2c), and \( g^h \)- before voiced aspirates (2d).

(2) underlying form   surface form   gloss
a.  \( k\text{-ert}^h\text{-a-m} \)   \( \text{kert'am} \)   I will go
    \( k\text{-t}^h\text{-a-m} \)   \( \text{kam} \)   I will give
    \( k\text{-kien-a-m} \)   \( \text{kakienam} \)   I will exist
b.  \( k\text{-bizz-a-m} \)   \( \text{gabizzam} \)   I will buzz
    \( k\text{-l-a-m} \)   \( \text{galam} \)   I will cry
    \( k\text{-z}^r\text{-a-m} \)   \( \text{gaz Ramirez} \)   I will bray
c.  \( k\text{-tox-n-ie-m} \)   \( \text{k'tokniem} \)   I will allow
    \( k\text{-t}^h\text{fap}^h\text{-ie-m} \)   \( \text{k't佛法p'iem} \)   I will measure
    \( k\text{-x}^\text{nd}-a-m \)   \( \text{k'xandam} \)   I will laugh
    \( k\text{-savor-ie-m} \)   \( \text{k'savoriem} \)   I will grow accustomed to
d.  \( k\text{-b}^h\text{eier-ie-m} \)   \( \text{g'ab'ieriem} \)   I will carry
    \( k\text{-g}^h\text{-o-m} \)   \( \text{g'goom} \)   I will come
    \( k\text{-d}^h\text{-n-ie-m} \)   \( \text{g'd' anniem} \)   I will put
    \( k\text{-d}^\text{z}^r\text{ev-ie-m} \)   \( \text{g'dzieviem} \)   I will form

What we are dealing with here is clearly a case of assimilation: the future prefix \( k^- \) assimilates in voicing and aspiration to a following consonant. The fact that the features responsible for voicing and aspiration spread together constitutes strong evidence for the popular theory (e.g. Sagey 1986) that the feature geometric representation of segments includes a Laryngeal node, which dominates the features [spread glottis] (responsible for aspiration) and [stiff vocal folds] (responsible for voicing), as schematized in (3).

(3) Laryngeal

[spread glottis]   [stiff vocal folds]

1 \( r \) represents a rhotic tap; \( \hat{r} \) is a rhotic trill.
With this structure in hand, we can interpret the alternations of the future prefix in (2) as the result of a rule that spreads the Laryngeal node to the $k$- from a consonant to its immediate right, as shown in (4) (intermediate nodes omitted).

(4) Laryngeal spreading

\[
\begin{array}{cc}
\newcommand{\myvec}[1]{\mathbf{#1}}
\myvec{k} & \text{[+cons]} \\
\myvec{#} & \\
\text{Laryngeal} & \\
\end{array}
\]

The rule of Laryngeal spreading precedes a rule of epenthesis that inserts a schwa after unsyllabified consonants.

Crucially, the fact that voiceless fricatives cause the prefix to surface as aspirated $k^h$ rather than unaspirated $k$ (2c) suggests that voiceless fricatives are [+spread glottis]. Voiced fricatives, on the other hand, do not trigger aspiration (2b), suggesting that they are [-spread glottis].

1.2. New Julfa voiceless fricatives

The same assimilation of laryngeal features in consonant clusters that we observed in the case of the future prefix also occurs in morpheme-internal clusters. New Julfa possesses a rule that deletes unstressed high vowels, leading to alternations of the type in (5).

(5) \begin{tabular}{l|l|l}
base form & genitive & gloss \\
\hline
kúft & $k^h$afûn & side \\
hieıkùs & $hieik^h$asûn & behind \\
\end{tabular}

Again, underlying $k$ becomes [+spread glottis] before voiceless fricatives (cf. Atfarijan 1940:§123). Though I have not found any synchronic alternations of this type with other
voiceless stops, the same behavior can be seen in the historical treatment of original plain
voiceless stop + voiceless fricative sequences, as in (6).

(6)  Classical Armenian  New Julfa  gloss
  psak  pʰəsak  crown
  (Turkish) bəfərti  pʰəfərtʰi  headscarf
  gifer  kʰəfer  evening

As in the case of the Laryngeal spreading in (4), the processes in (5) and (6) only make sense if
we assume that voiceless fricatives are [+spread], and this [+spread] specification spreads to the
preceding consonant. Voiced fricatives again must be [-spread] in order to avoid triggering the
rule.

Further evidence for the claim that voiceless fricatives are [+spread glottis] comes from the
treatment of Greek loanwords in Classical Armenian. Forms of the type in (7a) show that Greek
psi (i.e. the phoneme sequence /ps/) is rendered in Classical Armenian as a sequence of aspirated
pʰ + s; similarly, (7b) shows that Greek ksi (i.e. the phoneme sequence /ks/) is rendered as
aspirated kʰ + s. These facts are particularly striking given that Classical Armenian allows -ps-
dusters (e.g. psak 'crown'), and generally renders Greek p and k as Armenian p and k, not pʰ and
kʰ (7c).

<table>
<thead>
<tr>
<th>(7)</th>
<th>Greek</th>
<th>Classical Armenian</th>
<th>gloss</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>Ψαμμετικος (Psammetikʰos)</td>
<td>Pʰsammetikos</td>
<td>Psammetichus</td>
</tr>
<tr>
<td></td>
<td>ψαλμος (psalmos)</td>
<td>pʰsalmos</td>
<td>psalm</td>
</tr>
<tr>
<td></td>
<td>απνιθιον (apsințio)</td>
<td>apʰsniłin</td>
<td>wormwood</td>
</tr>
<tr>
<td>b.</td>
<td>Ξερκσες (Kserkses)</td>
<td>Kʰserkʰses</td>
<td>Xerxes</td>
</tr>
<tr>
<td></td>
<td>ξεστιες (kستيئس)</td>
<td>kʰseti</td>
<td>sextary, jar</td>
</tr>
<tr>
<td></td>
<td>δουκς (douks) (&lt; L. dux)</td>
<td>dukʰs</td>
<td>leader, prince</td>
</tr>
</tbody>
</table>
The data in (7) can be accounted for with exactly the same rule used to explain the data in (5) and (6). According to this rule, the [+spread glottis] specification of the s spreads to an immediately preceding consonant, resulting in aspiration of the immediately preceding p and k in (7a, b).

The same rule accounts for the Armenian treatment of the Indo-European word for twenty, *(d)wi-kins-. Given the normal Armenian-Indo-European sound correspondences, we should expect the Armenian reflex of this Indo-European protoform to be *gsan, but in fact the Armenian form is k'san. However, given the rule of Laryngeal spreading in (4) that we just postulated, this seemingly unexpected historical outcome now makes sense: the Laryngeal node of the s, which dominates the features [+spread] and [+stiff], spreads to the preceding g of the protoform *gsan, producing the attested form k'san.2

The same behavior of stop + fricative sequences is attested in Sanskrit by the ancient Indian phoneticians. According to the Rg Praśīfakṣja 13.16 (Varma 1929:73), the Taittiriya Praśīfakṣja 14.12 (Whitney 1868), and several other contemporary Indian phoneticians, underlying stops become aspirated before fricatives (which in Sanskrit consists of the set {śṣṣ}), as in the examples in (8).3

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2 Rule (4) must not have been active at the time when psak ‘crown’ was borrowed into Armenian from Middle Iranian.
3 The Aṭarvaveda Praśīfakṣja 2.6 (Whitney 1862) restricts the target of the aspiration rule to word-final stops. Interestingly, the Taittiriya Praśīfakṣja 14.13 mentions that according to the
The process of aspiration observed by the phoneticians can be formalized as a rule that spreads the Laryngeal node of fricatives to a preceding stop, as in (9).  

\[(9) \quad [-\text{son}] \quad [-\text{son}] \\
\quad [-\text{cont}] \quad [+\text{cont}] \\
\quad \text{Laryngeal}\]

The theory presented here predicts that voiced fricatives would spread their [-spread] specification to a preceding stop; in other words, they would not trigger aspiration. Since Sanskrit does not possess voiced fricatives, however, this prediction cannot be tested. We can conclude, though, that voiceless fricatives must be [+spread] in order to trigger the aspiration rule. The phonological evidence adduced here accords with the phonetic observations of the ancient Indian phoneticians, who state that the Sanskrit fricatives and voiceless aspirates form a class of aspirates, to the exclusion of plain voiceless consonants (e.g. Taittirīja Prātisākhyā 2.11; Whitney 1868.55).

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grammarians Vāḍabhīkara, the aspiration rule does not apply when the fricative is homorganic with the stop.  

\(^4\) The Sanskrit facts do not actually provide any evidence that it is the Laryngeal node rather than just the feature [spread glottis] that is spreading. I assume the stronger hypothesis, though, since there is also no evidence that laryngeal features other than aspiration are not involved in this process.
1.3. Fricative Assimilation

Our final piece of evidence concerning the behavior of laryngeal features in consonant clusters again comes from the Armenian dialect of New Julfa. In this dialect, original plain voiced stops regularly become voiced aspirates (10a), except after nasals (10b).

<table>
<thead>
<tr>
<th>Classical Armenian</th>
<th>New Julfa</th>
<th>gloss</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. berem</td>
<td>b'eriem</td>
<td>I carry</td>
</tr>
<tr>
<td>gini</td>
<td>g'ini</td>
<td>wine</td>
</tr>
<tr>
<td>dew</td>
<td>d'ev</td>
<td>demon</td>
</tr>
<tr>
<td>dzmein</td>
<td>d'zmeir</td>
<td>winter</td>
</tr>
<tr>
<td>dzur</td>
<td>d'zur</td>
<td>water</td>
</tr>
<tr>
<td>b. bambak</td>
<td>b'ambak</td>
<td>cotton</td>
</tr>
<tr>
<td>gangat</td>
<td>g'angat</td>
<td>complaint</td>
</tr>
<tr>
<td>andam</td>
<td>andam</td>
<td>limb</td>
</tr>
<tr>
<td>andzrew</td>
<td>andzrew</td>
<td>rain</td>
</tr>
<tr>
<td>kamurdz</td>
<td>karmundz</td>
<td>bridge</td>
</tr>
</tbody>
</table>

When a voiced fricative immediately precedes one of these voiced aspirates, it becomes voiceless, as one can see in (11).

<table>
<thead>
<tr>
<th>Classical Armenian</th>
<th>New Julfa</th>
<th>gloss</th>
</tr>
</thead>
<tbody>
<tr>
<td>anzgam</td>
<td>an'g'am</td>
<td>wicked</td>
</tr>
<tr>
<td>zgoj f</td>
<td>z'guf</td>
<td>safe</td>
</tr>
<tr>
<td>zgal</td>
<td>z'gal</td>
<td>feel</td>
</tr>
<tr>
<td>žekdel</td>
<td>žek'del</td>
<td>strangle</td>
</tr>
<tr>
<td>ažbiwr</td>
<td>až'wur</td>
<td>fountain</td>
</tr>
<tr>
<td>žbašum</td>
<td>žbas'um</td>
<td>business</td>
</tr>
<tr>
<td>žkžal</td>
<td>žkžal</td>
<td>repent</td>
</tr>
<tr>
<td>ožkžoijn</td>
<td>ožkžoijn</td>
<td>greeting</td>
</tr>
</tbody>
</table>

Voiced aspirates are treated in two different ways in the literature. One camp, composed primarily of phoneticians, represents voiced aspirates by means of [murmur], a feature distinct
from the conventional feature [voice] (Ladefoged 1993:144). In this model, the devoicing of fricatives in (11) cannot be interpreted as a rule spreading [murmur], because the voiceless fricatives produced by the rule are not murmured. Nor can it be interpreted as a rule of dissimilation, because in this model the feature [voice], which changes in the fricative, bears no phonological relationship to the feature [murmur], which triggers the change⁵. In sum, the murmur model fails to account for the facts in (11).

The other camp, represented by the work of Halle and Stevens (1971), views voiced aspirates as [-stiff, +spread] segments. In this view, the phonetic murmur characteristic of voiced aspirates is a by-product of the competition between the phonological specifications [-stiff] and [+spread]. Halle and Stevens’ representation of voiced aspirates makes possible a more plausible analysis of the process in (11). Let us suppose that there is a rule that spreads the feature specification [+spread] from right to left in clusters, as in (12).

(12) [+cons] [+cons]  
     \_\_\_\_  
     [+spread]

When a fricative precedes a voiced aspirate, it should become [+spread] by rule (12). Since voiceless fricatives in our model are already [+spread], rule (12) will have no visible effect in this case. With voiced fricatives, however, rule (12) should produce the configuration [-stiff, +spread], i.e. a voiced aspirated fricative. This type of fricative does not appear to be allowed in natural languages, presumably because the amount of airflow required to cue the presence of the feature [+spread glottis], and to indicate that the segment is a fricative, is too great for the vocal

⁵ Additional arguments against the feature [murmur] are given in Halle 1973.
folds to be able to maintain a [+stiff] configuration. I propose that the disallowed configuration *[+stiff, +spread] is repaired so as to yield a [+stiff, +spread] segment, in other words a voiceless fricative. This procedure is directly analogous to what we find in Icelandic, where stops spread their specification for the feature [spread glottis] to a preceding sonorant. When the sonorant becomes [+spread] as a result of this rule, it devoices (Thráinsson 1978). The devoicing of English liquids following voiceless stops in words such as pray [p'rej] can be explained in a similar manner (cf. Iverson and Salmons 1995).

As with the other cases presented in this section, the behavior of New Julfa fricative devoicing only makes sense if we assume that voiceless fricatives are [+spread] and voiced fricatives are [-spread]. If all fricatives were [-spread], we would have to say that voiceless fricatives delinked the [+spread] specification spread by rule (12); voiced fricatives, on the other hand, would have to delink both [+spread] and [-stiff]. This analysis would miss the generalization that fricatives behave as a natural class, since voiced and voiceless fricatives would trigger different repair strategies. If on the other hand all fricatives were [+spread], we would expect that rule (12) would have no effect on voiced fricatives, which is incorrect.

2. Delinking

Further evidence for our representation of fricatives comes from the treatment of fricative-stop sequences in the Middle Indic language Pali. In this language, original Indic fricative + stop

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6 The framework of constraints and repairs employed here is based on Calabrese 1995, to which we return in section 4.
sequences (here represented by Sanskrit forms) surface as voiceless aspirates in initial position (13a) and postaspirated geminates in medial position (13b).7

(13)  | Sanskrit | Pali | gloss  
---|--------|-----|-------
 a. initial | skandā- | k'andā- | shoulder  
 | stāna- | t'ana- | breast  
 | sparfa- | p'assā- | touch  
 b. medial | hāśia- | harrā- | hand  
 | yaṣṭī- | yaṭṭi- | pole  

The changes represented in (13) result from a general simplification of syllable structure that occurred between Old Indic (Sanskrit) and Middle Indic (Pali, Prakrit, etc.). Whereas Sanskrit allowed complex onsets (14a) and place features in codas (14b), Middle Indic did not (14c, d). Violations of the new syllabic constraints were repaired by deleting the offending segments. In onset position, this delinking resulted in the total disappearance of the segment (14c). In coda position, however, the timing unit vacated by the delinked segment associates to the following onset segment, yielding a geminate (14d).

(14)  | Sanskrit | Pali | gloss  
---|--------|-----|-------
 a. krāma- | c. kama- | step  
 b. ukta- | d. utta- | spoken  

What is relevant for our purposes is the fact that the laryngeal features of the delinked segments survive. In stēna- ‘breast’ (13a), for example, the initial s delinks (15a), but the floating [+spread]

7 Iverson and Salmons 1995 suggest that there is a mismatch between the underlying and surface representations in postaspirated clusters of this type: whereas in the acoustic output only the final member of the cluster is aspirated, in the underlying phonological structure all members of the
specification of the $s$ then attaches to the following segment (15b), producing a voiceless aspirate (15c).

(15)  
  a. debuccalization  
    \[ \begin{array}{ccccccc} 
      X & X & X & X & X \\ 
      \downarrow & \downarrow & \downarrow & \downarrow & \downarrow \\ 
      s & t & a & n & a \\
    \end{array} \quad [\text{+spread}] \]
  b. laryngeal attachment  
    \[ \begin{array}{ccccccc} 
      X & X & X & X & X \\ 
      \downarrow & \downarrow & \downarrow & \downarrow & \downarrow \\ 
      s & t & a & n & a \\
    \end{array} \quad [\text{+spread}] \]
  c. final surface form  
    \[ \begin{array}{ccccccc} 
      X & X & X & X \\ 
      \downarrow & \downarrow & \downarrow & \downarrow \\ 
      t^h & a & n & a \\
    \end{array} \quad [\text{+spread}] \]

A similar process occurs in the synchronic phonology of the Seville dialect of Spanish (Javier Martin-Gonzales, personal communication). As in many dialects of Spanish, $s$ debuccalizes in coda position. Unlike other dialects, however, the debuccalized $s$ does not simply surface as $h$ when it precedes a stop; rather, it also aspirates the following stop, as in (16).

(16)  
  underlying form  
    \textit{los padres}  
  surface form  
    \textit{lo\'h p\'a\'dre\'h}  
  gloss  
    the parents

Cluster are linked to a single [spread glottis] specification. I will not discuss this idea further here, as it is not directly relevant to the theory that I am proposing.
The Pali and Spanish cases can only be accounted for by assuming that voiceless fricatives are [+spread]. If the Spanish s were [-spread], for example, we would be unable to account for the [+spread] specification that appears on the underlying p in (16).

4. Corroborative Evidence

The laryngeal specifications for fricatives proposed in this paper have the additional advantage of allowing us to make sense of important components of two well-known but heretofore problematic phonological phenomena, post-nasal voicing and tonogenesis. In this section I first consider how to treat post-nasal voicing in languages such as Armenian and Greek, and then turn to tonogenesis in Thai.

4.1. Post-Nasal Voicing

The phenomenon of post-nasal voicing is extremely common cross-linguistically, and has attracted a great deal of attention from phonologists in recent years (see Pater (forthcoming) for a review of the relevant literature). However, existing accounts have not provided a satisfactory explanation for the failure of fricatives and aspirates to undergo post-nasal voicing. In this section I show how we can use the theory of laryngeal specifications presented in this paper to account in a unified way not only for the behavior of fricatives and aspirates, but also for the behavior of continuants.
A typical case of post-nasal voicing occurs in the historical development of Modern Greek, where stops and affricates (17a) but not fricatives (17b)\(^8\) are voiced after nasal consonants.

\[
\begin{array}{lll}
(17) & \text{Classical Greek} & \text{Modern Greek} & \text{gloss} \\
a. & olimpos & olimbos & Olympus \\
& kenuron & kendro & center \\
& ankura & angira & anchor \\
b. & antropos & antropos & man \\
& melankolia & melancholia & melancholy \\
\end{array}
\]

Post-nasal voicing is still active in the synchronic phonology of Modern Greek, as shown by the alternations in (18) (data from Pring 1962:19).

\[
\begin{array}{lll}
(18) & \text{underlying form} & \text{surface form} & \text{gloss} \\
a. \text{ stops} & sion kipo & stengipo & in the garden \\
& den pirazi & dembiraizi & it doesn’t matter \\
& en vaksi & endaksi & all right \\
b. \text{ affricates} & ion psigo & tombzigo & (all) souls’ (day) \\
& sin tsanta tis & stindzandatis & in her bag \\
& san ksiloi & sangzilo & like wood \\
\end{array}
\]

Sagey (1986) interprets post-nasal voicing processes of this type as the spreading of [-stiff] from a nasal consonant to a following consonant (19a). She and other phonologists (cf. Padgett 1991) who have dealt with post-nasal voicing assume that it creates a linked structure (in effect, a prenasalized stop; (19b)). This linked structure is not allowed to contain the feature combination * [+nasal, +continuant], since it is difficult to produce continuancy when the velum is lowered (19c). Consequently, post-nasal voicing is blocked from applying to [+continuant] consonants.

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\(^8\) Note that the outcomes are not *anovoritis, *anetropos, *melanxolias, though Modern Greek has
(19) post-nasal voicing in the spirit of Sagey 1986 and Padgett 1991 (relevant features only)

a. spreading

\[
\begin{array}{c}
\text{[+cons]} & \text{[+cons]} \\
\text{[+nasal]} & \text{[-stiff]}
\end{array}
\]

b. result: linked structure

\[
\begin{array}{c}
\text{[+cons]} & \text{[+cons]} \\
\text{[+nasal]} & \text{[-stiff]}
\end{array}
\]

c. illicit structure: *[+nasal, +continuant]

\[
\begin{array}{c}
\text{[+cons]} & \text{[+cons]} \\
\text{[+nasal]} & \text{[-stiff]} & \text{[+cont]}
\end{array}
\]

Sagey's analysis, as well as the analyses of post-nasal voicing comprehensively summarized by Pater (forthcoming), ignore the crucial cases of post-nasal voicing, however, which occur in languages with richer systems of laryngeal contrasts. In these languages, such as New Julfa, we can see that post-nasal voicing is blocked not only with fricatives (20b), but also with aspirated consonants (20c).

\[ /\gamma/, /\delta/, \text{ and } /\nu/ \text{ phonemes.}\]
(20) | Classical Armenian | New Julfa | gloss  
|-----------------|-----------|--------  
| a. əntsaj       | əntsa      | gift    
| ankanel         | ənganiel   | fall    
| tfantʃ          | tfandʒ     | fly     
| ajneł           | əndieʃ     | there   
| b. —             | insaf      | justice  
| —                | ənsunakviel | starve   
| —                | ənʃieʃ      | give false hopes   
| —                | sensuri     | type of melon    
| c. t'antʃel      | t'antʃin ʃal | mutter  
| fampʰur          | fampʰur    | spit    
| jawnkʰ           | ʃunkʰ      | eyebrow 

The rule of post-nasal voicing belongs to the synchronic phonological system of New Julfa, as can be seen in the fact that it applies in clusters created by a synchronic rule of vowel syncope (21).  

(21) | nominative | genitive | gloss  
|--------|---------|--------  
| kənɪkl | kənga   | wife   
| g'ɔrtənuk | g'ɔrtənga | frog  

Sagey’s analysis cannot account for the failure of voiceless aspirates to undergo post-nasal voicing. Since voiceless aspirates are [-continuant], we expect them to become voiced, but they do not. The theory we have developed in this paper suggests another solution, however. In our model, but not in Sagey’s, the fricatives in (17), (18), and (20) share with voiceless aspirates the feature specification [+spread glottis]. Furthermore, the feature combination [+nasal, +spread] is highly marked, as it is difficult to sustain oral aspiration noise—the primary acoustic correlate of [+spread glottis]—when the velum is lowered. In the terms of Calabrese’s theory of markedness, the articulatory complexity and rarity in phonological systems of this particular feature configuration is captured by a marking statement of the form in (22), which states that aspirated nasal segments are phonologically marked.
(22)  *[+nasal, +spread]

Given our assumptions that voiceless fricatives are [+spread] and that UG contains the marking statement in (22), we can now account for both the Greek and the New Julfa facts, with only minimal modification to Sagey's original analysis. In our analysis, post-nasal voicing spreads the feature [-stiff vocal folds] from a nasal consonant to a following obstruent, creating a linked structure (cf. (19a)). Since linked structures are treated by marking statements as single segments, post-nasal voicing makes visible to these marking statements the [spread] specification of the segment to which the [-stiff] feature of the nasal has spread. If this segment happens to be [+spread], the linked structure contains the disallowed configuration *[+nasal, +spread] (cf. (19c)). This disallowed configuration is subsequently repaired via delinking of the [-stiff] feature from the target segment.

4.2. Thai Consonant Classes

The laryngeal specifications proposed in this paper also allow us to make sense of one aspect of tonogenesis in the history of Thai. It is well-known that the tones that developed on Thai vowels somewhere between the fifteenth and seventeenth centuries (Hudak 1987:763) were determined by the quality of neighboring consonants. The Thai consonants fell into three groups with respect to the tones which they engendered.9 These groups are schematized in (23).

9 I do not present here the tonal outcomes themselves, because they are not directly relevant to our discussion.
(23) Thai consonant classes

I voiceless aspirates, voiceless fricatives, voiceless sonorants

II plain voiceless stops

III voiced sounds (vowels, voiced sonorants, voiced aspirates)

Note that voiceless fricatives pattern with voiceless aspirates (group I), rather than unaspirated stops; note also that voiced fricatives pattern with voiced stops (group III), and not aspirates. We can rewrite the groupings in (23) in terms of the natural classes in (24).

(24) Thai consonant classes, revised

I [+spread glottis, +stiff vocal folds]

II [-spread glottis, +stiff vocal folds]

III [-stiff vocal folds]

Note that only the theory of laryngeal specifications proposed in this paper allows us to group the obstruents correctly with respect to their phonological effects in the evolution of Thai tones. Given the theory we have been developing, we expect the voiceless fricatives to fall into group I, since they are [+spread]. ¹⁰ Theories which maintain that voiceless fricatives are [-spread] cannot

¹⁰ The fact that the voiceless sonorants also belong to class I supports the idea that they are [+spread glottis] as well (cf. Ohala and Ohala 1993, Silverman 1995, Asano 1997).
account for the distribution in (23). By the same token, theories which maintain that all fricatives are [+spread] cannot account for the fact that voiced fricatives do not pattern with group I.

5. Conclusions

The Armenian, Indic, Spanish, Greek, and Thai facts discussed in this paper provide strong phonological evidence that voiceless fricatives are specified as [+spread glottis] and voiced fricatives are [-spread glottis]. These pieces of phonological evidence dovetail well with the phonetic facts mentioned earlier, namely that voiceless fricatives are produced with a spread glottis (Kingston 1990, Stevens 1991) and voiced fricatives are not (Catford 1977).

It should be noted that these specifications represent the unmarked state for fricative systems, rather than an absolute and invariable set of specifications. It is perfectly possible for languages to contrast [spread] values in voiceless fricatives allophonically (as in English) or phonemically (as in Burmese); it also appears that in some languages, such as Chinese, both the voiced and voiceless fricative series are [-spread] (Kevin Herwig, personal communication). Systems of the Chinese type are simply more marked than systems of the Armenian type, and hence they appear in fewer of the world’s languages. In the terms of Calabrese’s (1995) theory of markedness, UG provides a marking statement of the form in (25),

\[(25) \quad *[+\text{stiff}, -\text{spread}] / [\_ , +\text{continuant}]\]

which states that [-spread] voiceless fricatives are phonologically more complex than [+spread] voiceless fricatives (the marking statement also reflects the fact that voiceless vowels are generally
[+spread], but I will not consider this fact here). Voiced fricatives that are [+spread] are ruled out by a marking statement of the form in (26) (cf. Calabrese 1988:274).

(26)  *[+stiff, +spread] / [−, +continuant]

The laryngeal specifications of the fricatives in the languages considered in this paper cannot be derived from the structure of the stop inventory. In a two-series laryngeal system contrasting plain voiced and voiceless aspirated obstruents, such as we find in Standard Western Armenian, one could say that the voiceless fricatives are predictably [+spread] because all voiceless obstruents are [+spread]. This reasoning cannot work for languages like New Julfa or Sanskrit, though, where voiceless obstruents are not predictably [+spread], nor are voiced obstruents predictably [−spread].

It should be noted that the theory presented here is primarily a theory of phonological rather than phonetic representations. Though I believe that the phonological representations proposed here are well-grounded phonetically, some phonetic questions remain. For example, both Ken Stevens and Louis Goldstein have independently pointed out to me that, like voiceless fricatives, voiced fricatives also require some spreading of the glottis in order to produce sufficient airflow to yield frication noise; however, the degree of spreading is not as great as it is for voiceless fricatives. I do not consider this to be a problem, however, given that voiceless fricatives clearly pattern differently from voiced fricatives with respect to phonological processes.

The important point to bear in mind here is that a phonological specification [−X], where X is any feature, does not entail that the component of the vocal tract activated by [X] is completely inert at the phonetic level. The English phoneme [/], for example, is specified in the phonology as
[-round], yet it is often implemented with some rounding of the lips. Similarly, vowels that are phonologically [-nasal] are often implemented with some airflow through the nasal passage by speakers of American English. The fact that in each of these cases a particular articulator is phonetically active to a certain degree does not entail that this activity is encoded in the phonological representation; for example, we do not want to say that English [i] is [+round] in the phonology, nor do we want to say that American vowels are phonologically [+nasal].

Rather, we should acknowledge that phonological features bisect a continuum of phonetic activity. In this view, [+nasal] for example represents lowering of the velum beyond a certain critical zone; [-nasal] represents any lesser degree of velar lowering. Similarly, [±spread glottis] should be defined in terms of a line drawn somewhere in the range of possible degrees of spreading of the vocal folds (27a), rather than in the all-or-nothing terms of spreading versus no spreading (27b).

(27)

a. definition of [±spread glottis] proposed here

\[
\begin{array}{c}
\text{maximum spreading} \\
\{ \text{[+spread glottis]} \} \\
\text{no spreading} \\
\{ \text{[-spread glottis]} \}
\end{array}
\]

b. all-or-nothing definition of [±spread glottis]

\[
\begin{array}{c}
\text{maximum spreading} \\
\{ \text{[+spread glottis]} \} \\
\text{no spreading} \\
\{ \text{[-spread glottis]} \}
\end{array}
\]
The assumption that voiceless fricatives are specified [+spread glottis] enables us to provide a unitary account for a wide range of seemingly disparate phenomena. On the one hand, we reflect in our phonological model phonetic properties of fricatives that hitherto had been observed by phoneticians but ignored by phonologists. In addition, we account for the phonological behavior of laryngeal spreading, fricative assimilation, and post-nasal voicing in Armenian, aspiration in Sanskrit, debuccalization in Middle Indic and Spanish, and tonogenesis in Thai. Within theories of phonology that do not adopt the representation of fricatives proposed here, the individual phenomena in this set become difficult to explain, and the common phonological thread uniting each is missed.

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