SHORT REPORT

Possible and impossible segments

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In this article we consider the relationship between phonetic possibility and phonological permissibility of segment types. We ask (i) are any phonetically impossible segments phonologically permissible? and (ii) are any phonetically possible segments phonologically impermissible? Our main focus is on answering (ii). We analyze the implications of the only relevant case we can find, which is in Cohn's (1990, 1993a) examination of nasality spreading in Sundanese, and relates to the description of glottal nasals (produced with glottal place of articulation and lowered velum). Cohn tentatively proposes that nasalized [h] and [ʔ] occur phonetically but not phonologically. We show that a persuasive theory of nasality spreading suggests otherwise, and it is supported by evidence from several languages. Our conclusion is that no sound argument exists for excluding any pronounceable segment from phonology on theoretical grounds. The relation between the phonetically possible and the phonologically possible accordingly becomes somewhat more straightforward.*

What is the relationship between pronounceability of segments on the phonetic level and licitness (or illicitness) of segments in terms of phonological theory? The question can be separated into two more specific questions about the relations between phonology and phonetics. Let us call a segment type PHONOLOGICALLY PERMISSIBLE if and only if no principle of phonological theory is infringed by the appearance of a segment of such type in an underlying representation or in the input/output of a phonological rule or level, and let us call a segment type PHONETICALLY POSSIBLE if and only if segments of such type can actually be pronounced. The cross-cutting of the two distinctions here (phonetic versus phonological and possible versus impermissible) defines four logical possibilities, but we will dismiss two of them immediately. We will assume that under every theory of phonology at least some phonetically possible segment types are phonologically permissible. We will also assume that every phonological theory bans some segment types that are phonetically impossible (both phonology and phonetics agree in the complete absence of apico-uvular stops, velar trills, and so on). This leaves two issues:

(1) a. Are any phonetically impossible segments phonologically permissible?
    b. Are any phonetically possible segments phonologically impermissible?

We believe there is enough coherent dispute about 1a that it must be acknowledged to be open, a topic of continuing legitimate debate. The proposals of several analysts amount to postulated licit phonological feature combinations that describe phonetically impossible segments. Ladefoged and Maddieson (1996:37–38) for example, give grounds for analyzing Dahalo (Cushitic) as having underlying voiceless and voiced epiglottal plosives, despite the phonetic fact that there is not enough expandable surface area to the vocal tract below an epiglottal closure to permit the transglottal airflow to initiate voicing (see Laufer 1991, Ohala 1983). Likewise, LuGanda (Bantu) has been analyzed as having voiceless consonants bearing phonemic tone (Ladefoged et al. 1968:

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40, Ladefoged & Maddieson 1996:94–95), and under certain assumptions about the description of tone in terms of F_0 this is a phonetic impossibility. Some analyses of Japanese phonology posit pitch accent on certain voiceless vowels (Hashimoto 1993), and this might amount to permitting phonetic impossibilities under some assumptions about the description of tone (but not all; for Halle and Stevens (1971) tone is an epiphenomenal result of changes in glottal tension that are not incompatible with voicelessness). Note also Chomsky and Halle (1968:161) and Krohn (1975) on phonetically contradictory glide and diphthong specifications, and Swadesh and Voegelin (1939) on a voiced glottal stop (discussed by McCawley 1969). These analyses may or may not be correct, but they seem to be within the range of current debate. The ongoing discussion suggests that question 1a must remain open.

Our focus here is on the complementary question 1b: whether phonetically possible segment types are ever defined as impermissible in phonology by a constraint in phonological theory. We argue that there is no warrant in the literature for answering this question in the affirmative. If we are right, the relation between the phonetically possible and the phonologically possible becomes somewhat more straightforward (though not trivial, as continued debate over 1a shows).

1. PHONETICALLY POSSIBLE BUT PHONOLOGICALLY IMPERMISSIBLE SEGMENTS. Scarcely anyone hitherto appears to have considered whether there are phonetically possible segments that are excluded by phonological theory from appearing in underlying inventories or playing a role in phonological rules or phenomena—that is, whether a segment type may be ruled unfit for phonological service despite having passed the physical. In fact, we have been unable to find the question raised anywhere other than in Cohn's studies of nasal spreading in Sundanese (1990, 1993a). While these articles make significant contributions—and we discuss them in detail below—ultimately we take a different position from Cohn. Her answer to question 1b is implicitly affirmative, because she proposes to exclude a class of phonetically possible segments from phonology by means of a constraint on the phonological representations of segments. We will bring new evidence to the issue to argue that 1b should be answered in the negative.

1.1. SUNDANESE NASAL HARMONY. Sundanese, an Austronesian language spoken in Java, has a type of spreading nasalization discussed in a classic paper by Robins (1957) and investigated in detail by Cohn (1990, 1993a). In Sundanese, nasalization spreads rightward from a nasal stop. The resulting distribution of nasality is illustrated by the forms in 2, transcribed using Robins's conventions (2d–g are from Cohn 1990:52, the remainder from Robins 1957). These data show that nasal harmony nasalizes vowels, even across syllables, but it is blocked by all other segments with a supralaryngeal place of articulation, including the semivowels [j] and [w].[1] (We use the term SEMIVOWEL to refer to supralaryngeal glides.)[2]

[1] This generalization about nasality spreading appears to be violated in forms produced by a productive process of pluralization, in which an infix [-ar-] or [-al-] occurs after the initial segment of the word. When the initial segment is a nasal, the nasality spreading overapplies such that vowels preceding and following the consonant of the infix are nasalized (Robins 1957, Cohn 1993a). Examples from Cohn (1993a:339) include [ɲ-ãl-ãũr] 'say (active)', [ɲ-ãl-ĩãr] 'seek (active)', [n-ãr-ĩʔĩs] 'relax in a cool place (active)', [m-ãr-ãhãl] 'expensive' (transcription of nasalization after Cohn). In studying the nasal airflow of these forms, Cohn (1993a:354) finds that the infixed [l] becomes nasalized (presumably as a consequence of its intervocalic nasal context, as suggested by Cohn 1993a:345), but [r] remains oral and imposes some of its orality on the following vowel. This phenomenon indicates that it is possible for discontinuous nasalization spans to occur in Sundanese; however, phonological analyses of these facts have been proposed maintaining the generalization that [nasal] spreading in Sundanese takes place between adjacent segments without skipping any intervening elements. The reader is referred to Anderson 1972 for a generative approach calling on (naturally) ordered

(2) a. ɲãĩãn 'to wet'
b. mõlohok 'to stare'
c. mãro 'to halve'
d. ŋãjak 'to sift'
e. mãwur 'to spread'
f. ŋãtur 'to arrange'
g. ŋũdag 'to pursue'

Interestingly, the glottal consonants, [h] and [ʔ] do not block nasality spreading, as shown by the forms in 3 (from Robins). We note that glottal stop in Sundanese is nonphonemic, because it occurs only in predictable environments, but Cohn argues that at least some glottal stops must be inserted in the phonology, as their site of epenthesis is sensitive to morphological boundaries (1990:66).

(3) a. kumãhã 'how?'
b. bɤŋhãr 'to be rich'
c. mĩʔãsih 'to love'

These data raise the question whether the glottal consonants participate either phonologically or phonetically in Sundanese nasal harmony. We claim that they do both.

1.2. Phonetic and phonological nasality. At the heart of this investigation is the issue of what it means to be nasal. Cohn characterizes the feature [nasal] such that [+nasal] corresponds to a lowered velum rather than requiring nasal airflow (see also Howard 1973:55). This interpretation, which we believe to be correct, has important consequences for the possibility of nasalizing glottal stop in a nasal context. Cohn remarks:

> There is no reason to assume that the velum changes its position during the glottal stop. Following the view that velum position, or more precisely velopharyngeal opening, is the primary phonetic correlate of [nasal], a glottal stop in such a case is phonetically nasal; yet perceptually, there would be no cue to this nasalization (1993a:347).

Cohn recorded filtered nasal airflow traces of words read by Sundanese speakers to measure the phonetic nasalization of segments, including glottals, in nasal contexts. In words where nasality has spread through [h], as for example in the form that Cohn transcribes as [mĩhãk] 'take sides (active)', she found a high level of nasal airflow throughout the glottal continuant, clearly indicating that the [h] is phonetically nasalized. These findings are also supported by Howard's (1973:54–55) and Ohala's (1990: 165) interpretation of nasalization of [h] in kymographic tracings presented in Robins 1957, and by the instrumental study of Sundanese performed by Condax et al. 1974.

rules (Anderson assumes that glottals are skipped in [nasal] spreading but liquids are not). Van der Hulst & Smith 1982 suggests a derivational analysis in which the [nasal] spreading rule applies cyclically. More recently, Benua 1997 proposes a nonderivational optimality theoretic account drawing on the notion of paradigm uniformity. We conclude that the overapplication of nasalization in infixed forms is explained by a phonological account such as those cited above (although we take no position here as to which of these should be adopted), and supralaryngeal consonants thus consistently function as blockers of phonological nasality spreading in Sundanese.

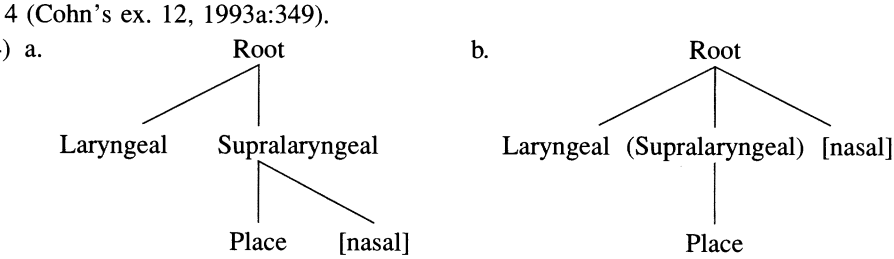
[2] Cohn (1990, 1993a) distinguishes two types of supralaryngeal glides in Sundanese. The first, the kind transcribed in 2, is underlying and blocks [nasal] spreading. The second is a brief transitional glide epenthesized between two adjacent vowels. These latter glides become nasalized in Sundanese and are not shown in the above transcription. We will not be concerned with these transitional glides in our discussion of Sundanese, and use the term semivowel to refer to the underlying glides.

In the case of glottal stop in a nasal span, as in the form that Cohn transcribes as [nĩʔĩs] 'relax in a cool place (active)', the traces taken by Cohn show a significant decrease in nasal airflow between the nasal vowels, which, as Cohn pointed out, is due to the air stoppage at the glottis. Importantly, the decrease in nasal airflow does not provide evidence that the velum has been raised during the glottal stop. In fact, we are not aware of any phonetic study finding evidence that the velum is raised in this context. Everyone who has looked closely at the matter seems to be in agreement that it remains lowered: Howard (1973:54–55), Cohn (1990, 1993a), Ohala (1990:165, n.10), Ohala and Ohala (1993:243, n. 2), and Ladefoged and Maddieson (1996:134) address this question for Sundanese; Durie (1985:10) says the same about the closely related Acehnese; Ohala (1972:1168) situates the issue with respect to general phonetics.

Note that the specification [+nasal] must be interpreted in terms that make reference to velopharyngeal port opening, not to nasal airflow. Although these two properties will often be correlated, they are not mutually dependent—the presence of nasal airflow is neither necessary nor sufficient to establish velic opening. It is not necessary because the velum can uncontroversially be lowered during glottal stop, and it is not sufficient because the cleft palate condition permits nasal airflow without velic lowering (not a normal language situation, of course, but sufficient to show the possibility of nasal airflow simultaneous with a raised velum). Defying etymology then, the feature [nasal] is defined without reference to the nose.[3] Nasal airflow is epiphenomenal.[4]

1.3. The status of glottal nasals in Sundanese phonology. Cohn does not doubt that glottals in Sundanese can be phonetically nasal and in fact provides instrumental support for that claim. But, she questions the phonological permissibility of these segments. On this subject, she considers the two alternative feature geometry structures in 4 (Cohn's ex. 12, 1993a:349).

(4)



In 4a [nasal] is posited as a dependent of the supralaryngeal node. This structure makes

[3] This interpretation of [+nasal] is suggestive of a revision to the IPA chart. The cells corresponding to the glottal and pharyngeal nasals are shaded in the current (1996) chart. But the segments in question are phonetically possible: there is no articulatory difficulty associated with lowering the velum during a glottal stop, nor for that matter during a pharyngeal or epiglottal one; in fact the evidence surveyed in Matisoff 1975 (note also Ohala 1972) suggests these places of articulation often correlate with velic lowering. We propose that the 'Nasal' row of the IPA pulmonic consonant chart should have no shading at all.

[4] Cohn (1993a) and Padgett (1995:49), among others, have made this point. The implications for instrumental investigation are touched on by Condax et al. (1974), who, in discussion of their ingenious technique for recording nasal airflow, note that 'Ohala's nasograph has an advantage ... in that the nasograph monitors the position of the velum even during glottal stop' (1974:301). Techniques such as the nasograph (which measures the light reaching a sensor in the nasal cavity above the velum from a small light inserted below the velum), and others such as cinefluorography, can reveal that a glottal nasal stop is indeed possible. The articulatory correlates of [+nasal] are often overstated, saying that nasals are articulated with the velum lowered so that, or with the result that, nasal airflow occurs (see for example Chomsky & Halle 1968:316; Ohala 1975:295; Ladefoged 1993:8; Ladefoged & Maddieson 1996:102). We suggest that these definitions be revised to say simply that nasals are articulated with the velum lowered.

the theoretical claim that only supralaryngeal segments can be phonologically nasal, and glottals would thus be expected never to participate in nasal harmony. In contrast, the structure in 4b posits the feature [nasal] as anchored to the root node. This structure allows for phonologically nasal glottals, and thereby permits the possibility that glottal consonants undergo phonological nasal harmony. Cohn adopts the structure in 4a, thereby excluding the possibility of phonologically nasal glottal segments, though she notes that further evidence is needed to determine the correct structure.

2. PHONOLOGICAL NASALITY IN GLOTTAL CONSONANTS. Taking up the issue raised by Cohn's proposal, we now turn to an examination of the evidence needed to decide between the two structures in 4. In what follows, we argue that the phonological nasalization of glottals must be recognized. We take no position here in favor of a particular feature geometry, nor of the theory of feature geometry. What we are claiming is that whatever one's representational assumptions, [nasal] must be a possible phonological property of glottals. Thus, if the representational assumptions adopted were those of Cohn 1993a, then the structure in 4b, in which [nasal] is a dependent of the root node, would be the appropriate representation.

The evidence we present for the phonological nasalization of glottals is somewhat different for the continuant and stop segment types. In the case of glottal continuants we cite four languages in which a nasalized glottal continuant behaves as a trigger for a phonological nasal spreading; in three cases there is evidence that [h̃] has a phonemic status. In the case of the glottal stop, the lack of perceptibility of nasalization renders the occurrence of phonemic nasalization less likely (we address the ramifications of this in §4). For these segments, we discuss a case in which nasalization carries through a phonemic glottal stop and then present a theoretical argument that it participates phonologically in the [nasal] spreading.

2.1. AFRICAN EVIDENCE. A convincing argument for phonologically nasal glottal continuants comes from Ladefoged and Maddieson's description of Kwangali (Kavango; Namibia). Ladefoged and Maddieson posit an underlying contrast between a nasal and a nonnasal glottal approximant. Their rationale is as follows. Instrumental measurements show that some glottal continuants are nasalized, and when they are nasalized, the following vowel is as well. Yet nasal vowels have a noncontrastive distribution, because they occur only in the context of nasal consonants. Nasality on [h] is thus concluded to be phonemic and spreads to nasalize the vowel, as illustrated in 5 (Ladefoged & Maddieson 1996:133).

(5) Phonological representation conjectured	Phonetic representation instrumentally verified
/h̃oh̃o/	[h̃õh̃õ] 'devil's thorn'

Several near minimal pairs supporting a phonemic contrast between a nasal and oral [h] are given in 6 (Ladefoged and Maddieson 1996:132).

(6) a.	/h̃oh̃o/	'devil's thorn'	e.	/hompa/	'chief'
b.	/h̃uh̃wa/	'fowl'	f.	/huma/	'bite'
c.	/muh̃o/	'kind of spear'	g.	/muhona/	'master'
d.	/koh̃i/	'beneath, under'	h.	/ruhunga/	'feather'

We note that an alternate approach in which nasality is attributed to the vowel or syllable rather than the glottal does not suggest itself here since nasal vowels have an allophonic distribution—they are restricted to the environment of nasal consonants and [h̃].

2.2. AMAZONIAN EVIDENCE. Further evidence for phonological nasality in glottal continuants can be found in certain Amazonian languages.

ARABELA. In Arabela (Zaparoan; Peru), described by Rich 1963, there is a rightward-spreading nasal harmony. Nasality spreads from nasal consonants, as in Sundanese, except that in Arabela, semivowels as well as vowels undergo nasalization. This phenomenon is illustrated by the forms in 7.

(7) a. mõnũˀ 'to kill'
b. mj̃æ̃nũˀ 'swallow'
c. nũw̃ãˀ 'partridge'
d. nj̃æ̃æ̃riˀ 'he laid it down'
e. kɪronĩˀ 'deep'

An interesting feature is that a nasal glottal fricative belongs to the set of consonants triggering nasal harmony, as shown in 8. This glottal segment is accordingly analyzed as phonemically nasal by Rich (1963:194) (the glottal fricative is phonetically nasal in all contexts; there is no contrasting oral glottal continuant).

(8) a. h̃ũw̃ãˀ 'a yellow bird'
b. h̃ẽẽgɪˀ 'termites'
c. h̃ĩj̃æ̃nĩˀ 'old woman'

We note that the glottal stop in Arabela is nonphonemic and occurs only to close an open final syllable at the end of a phonological phrase, so we cannot determine the behavior of this glottal in the nasal harmony of Arabela.

Once again, an analysis attributing nasality to the vowel or syllable is not indicated, since nasal vowels occur only in vocoidal sequences following a nasal consonant. It is plausible, however, that the etymological source of nasality in the glottal continuant of Arabela is RHINOGLOTTOPHILIA, the tendency for vowel nasalization to occur in the context of a glottal as a result of perceptual and articulatory factors (Matisoff 1975, Ohala 1972). Yet even if this were the original basis for the interpretation of nasality on [h] in Arabela, the feature [+nasal] must actually be present on the glottal in the phonology in order for it to trigger [nasal] spreading. In Kwangali, rhinoglottophilia is not a likely etymological factor, since oral and nasal glottal continuants have a contrastive distribution before vowels.

AGUARUNA. A further example of a nasalized glottal continuant triggering nasality spread occurs in Aguaruna (Jivaroan; Peru), described by Payne (1974). Payne notes that [h̃] triggers a bidirectional nasalization (in some cases just progressive) which targets vowels and semivowels and is blocked by other consonants, as illustrated in 9.

(9) a. ãh̃ũm 'later'
b. t͡sũh̃ĩ 'fish'
c. sũh̃ĩk 'beads'
d. ɨsãh̃ĩ 'ridge of roof'
e. kũh̃ũ 'porcupine'
f. sakãh̃ũ 'skeleton'

The nasalized glottal continuant is not phonemic in Aguaruna, although an oral [h] does have phonemic status. The glottal [h̃] is in complementary distribution with the velar nasal [ŋ], the former occurring syllable initially and the latter syllable finally. Payne (1974:49) and later Trigo (1988:124–25) analyze the nasalized glottal as derived through debuccalization of the velar nasal. Importantly, both their analyses agree that the derived glottal continuant is phonologically [+nasal] and triggers phonological spreading of nasalization.[5]

2.3. Austronesian evidence. Recent work by Blust (1998) uncovers firm evidence for an underlying nasal glottal continuant in Seimat (Austronesian; Melanesia)—one that contrasts with an underlying oral /h/. Seimat predictably nasalizes vowels after nasal stops, as is pervasive in the Austronesian family (Blust 1997, 1998). In addition, certain [h]s condition the presence of an adjacent nasal vowel, as seen by comparing 10a–d with 10e–h (transcription follows Blust).[6]

(10) a. hõŋ 'to hear'
b. hũhũa/hũohũ 'two'
c. mati(hũ)- 'to sleep'
d. wah(ã) 'root'
e. han 'to climb'
f. hil 'how much/how many?'
g. hon 'sea turtle'
h. utuhi 'draw water'

Blust discovers a historical source for this distinction: the non-nasalizing /h/ derives from Proto-Oceanic *p and the nasalizing ones derive from *r. Assuming that rhinoglottophilia was the original basis for nasalization in the following vowel, he notes that it has occurred only in the glottals developing from *r, suggesting that the change *r > /h/ may have preceded the change *p > (*f >) /h/.

Blust presents evidence that a final /i/ in many verb forms represents a transitive suffix. As expected, after nasal stops this vowel is nasalized. It is also nasalized in some of the forms where this suffix is preceded by a glottal continuant.

(11) a. tapahĩ 'slap someone or something'
b. tapuhĩ 'stab someone or something'
c. tihĩ 'pour something'
d. hatuhĩ 'make something stand'
e. wetahĩ 'open the eyes wide'

As Blust points out, this occurrence of the nasalized suffix alternant only after certain instances of [h] is indicative of a phonemic distinction in nasality in the glottal continuant. In pairs such as /ha-tuh̃-i/ versus /utuh-i/, he thus posits an underlying contrast between /h̃/ and /h/.

2.4. Nasal glottal stops. Turning now to the question of phonological nasalization of glottal stops, we consider Capanahua, a Panoan language of Peruvian Amazonia. Capanahua has leftward nasal harmony from nasal stops (Loos 1969). It targets vowels and semivowels, but is blocked by other supralaryngeal segments, as illustrated in 12.[7]

[5] Trigo (1988:125, n. 10) notes that a conceivable alternative is to treat [h̃] as a voiceless velar nasal. Payne (personal communication) acknowledges considering this possibility during his field research. He states that although he does not have instrumental evidence to verify it, from all his efforts to determine its articulation, it did not seem to involve a velar closure in the oral cavity.

[6] Certain velar glides in Seimat also trigger nasalization of an adjacent vowel. See Blust 1998 on the historical basis for this and a synchronic analysis.

[7] Word-final nasals in Capanahua are deleted but still trigger nasal spreading, so we have shown them in the transcription. Capanahua also deletes nasals in clusters containing a continuant consonant, in which case it triggers bidirectional spreading (the rightward spreading is not shown here). For analysis of this interesting phenomenon, see Loos 1969 and Trigo 1988.

(12) a. warãn 'squash'
b. põj̃ãn 'arm'
c. bãw̃ĩn 'catfish'
d. t͡ʃipõnki 'downriver'
e. bõõn 'hair'
f. wɯrãnwɯ 'push it'
g. bĩmɯ 'fruit'

Importantly for our argument, the phonemic glottal stop of this language (Loos 1969: 105) does not block nasal spread, as shown in 13.

(13) a. t͡ʃĩʔ̃ĩn 'by fire'
b. wɯrãnjasãʔ̃nwɯ 'push it sometime'

Thus while Sundanese showed that glottal stops do not necessarily stop nasal harmony from spreading, Capanahua reveals that the same can be true of underlying glottal stops. The implications of this fact will become clearer after we have set out in the next section the theory of the phonology of nasal harmony that we assume.

3. THE PHONOLOGY OF NASAL HARMONY. A core finding cutting across surveys of nasal harmony is that patterns of [nasal] spreading exhibit hierarchical variation (Schourup 1972, Pulleyblank 1989, Piggott 1992, Cohn 1993a, b, Padgett 1995; Walker 1995, 1998). The generalization is that systems of nasal harmony obey an implicational hierarchy, as in 14, where for each possible division marked by the labels ① through ④, all segments to the left will undergo nasalization, while those to the right will block. This hierarchy reflects the relative compatibility of [+nasal] (i.e. nasality) with different groups of segments, such that compatibility decreases moving from left to right.[8] The gradient compatibility of these classes of segments with nasalization has a phonetic basis that is discussed by Cohn (1993a) building on the earlier work of Ohala (1975) and others.[9]

(14) Vowels ① Semivowels ② Liquids ③ Fricatives ④ Obstruent Stops
← high———*compatibility with nasalization*———low →

This NASALIZATION HIERARCHY, which originated with Schourup (1972), figures in an important way in Piggott's (1992) significant study of [nasal] spreading patterns across languages. Piggott proposes to separate nasal harmony systems into two types. In TYPE A, segments are divided exhaustively into sets of TARGETS (segments that become nasalized) or BLOCKERS (segments that remain oral and block [nasal] spreading). In Piggott's analysis, it is Type A systems to which the hierarchical generalizations apply, and he presents examples of nasal harmony corresponding to each of the hierarchy splits marked in 14.

The second type of nasal harmony discussed by Piggott does not draw on the nasalization hierarchy. In this TYPE B harmony, segments are divided into a set of targets and a set of TRANSPARENT SEGMENTS (segments that remain oral but do not block [nasal] spreading). These systems do not display hierarchical variation, rather the transparent

[8] If nasality is better described in terms of a privative feature then we could represent it by monovalent [nasal] instead of binary [±nasal]. This distinction has no relevance to our concerns here.

[9] The nasalization hierarchy closely resembles the sonority scale, as noted, for example, by Cohn (1993a). The two hierarchies seem to differ, however, in the ranking of glottals, which would be ranked quite low on the sonority scale by many analysts, but are situated high in the nasalization hierarchy, as discussed in §3.1 (cf. Gnanadesikan 1995). See Boersma 1998:454–47 for arguments that this distinction can be understood by considering the functional basis for the two hierarchies (note also Walker 1998).

segments consist of a subset of the obstruents—typically voiceless—and the remaining segments are targets, consisting of sonorants and usually the voiced obstruents (well-known examples occur in the Amazonian languages Southern Barasano and Guaraní).[10]

Piggott's work represents a significant advance in the study of nasal harmony, from both a descriptive and theoretical perspective. It highlights an interesting point: the set of segments that are transparent in nasalization spreading is more or less constant; unlike the set of blocking segments, transparent segments are always limited to the class of obstruents rather than varying according to the steps of hierarchy. On the basis of this finding, it would appear that nasalization patterns with blocking segments versus those with transparent ones must be analytically divorced from one another, as Piggott proposes. But Walker, in a recent re-examination of this problem (1998), argues that the different nasalization patterns can be unified, and doing this brings new light to certain generalizations about nasal harmony.

Walker establishes a typology on the basis of a database of [nasal] spreading patterns in more than 75 languages, building on the background of Cohn's (1993b) survey of the status of the feature [nasal] across a wide range of languages and surveys of [nasal] spreading reported in Schourup 1972 and Piggott 1992. On the basis of this database, Walker proposes that the nasalization hierarchy be reinterpreted not as representing the possible splits between targets and blockers, but as representing the possible bifurcations between the sets of permeable segments and blockers, where PERMEABLE SEGMENTS are those that permit the continuation of [nasal] spreading. With this move, all nasal harmony patterns conform to some split in the nasalization hierarchy such that all classes of segments to the left of the split are permeable, while those to the right are blockers. Two further steps are added at either extreme of the hierarchy, as marked in 15.

(15) ⓪ Vowels ① Semivowels ② Liquids ③ Fricatives ④ Obstruent Stops ⑤
← high———*compatibility with nasalization*———low →

The leftmost step (⓪) corresponds to a language without [nasal] spreading: all segments belong to the set of blockers. The step at the rightmost edge characterizes a case in which all segments are permeable by nasalization, including the full set of obstruents. Examples of this kind are those in which all voiced segments become nasalized in nasal spreading and voiceless obstruents behave as transparent, i.e. the systems belonging to Piggott's Type B.

This merges target and transparent segmental behavior into one: permeable segment behavior. Three arguments for a class of permeable segments are adduced. First, Walker finds that with respect to the nasalization hierarchy, target and transparent segments in nasal harmony exhibit the same implications across languages: if a class of segments is targeted or is transparent, all classes of segments higher ranked in the nasalization hierarchy will also be permeable (i.e. transparent or targeted) by nasalization. Second, calling on the class of permeable segments in place of target segments yields a typology of nasal harmony in which all possible steps in the nasalization hierarchy are exhaustively attested.[11] Third, and perhaps most importantly, positing a split between permea-

[10] Piggott actually analyzes the separation as being between obstruents, which act transparent, and sonorants, which are targeted by [nasal] spreading. In making this claim, he suggests that the voiced oral or prenasalized stops belong to the class of sonorant consonants. This point is not relevant to our argument (though Walker 1998:§5.2 raises some problems for Piggott's claim). In our discussion we simply assume the usual obstruent characterization for the voiced (non-nasal) stops.

[11] Piggott obtains the nonexhaustive hierarchical variability of nasalization targets in his Type A harmony with his CONTRASTIVE NASALITY PRINCIPLE (1992:44). See Walker 1995 for empirical and theoretical arguments for rejecting this.

ble versus blocking segments achieves a unified understanding of nasal harmony. ALL nasal harmony patterns conform to the variation predicted by the nasalization hierarchy. As a result, no distinction in nasal harmony types is needed.

Within the set of permeable segments, two possible outcomes are distinguished for segments through which nasalization is propagated: they either become nasalized or they remain oral (in descriptive terms they are 'skipped'). The nasalized outcome occurs on permeated segments that have a minimal degree of compatibility with nasalization, a threshold usually met by all voiced segments. Walker notes that the oral outcome occurs only on segments near the extreme of incompatibility with nasalization, typically voiceless obstruents.[12] The details of Walker's formal analysis of these points do not concern us here; the relevant points about the revised application of the nasalization hierarchy are given in 16.

(16) a. The nasalization hierarchy characterizes possible variation in the sets of permeable versus blocking segments in nasal harmony.
b. All patterns of [nasal] spreading obey the nasalization hierarchy.[13]
c. Permeable segments have two possible outcomes: nasal or oral (oral referring to sounds produced with a raised velum). The latter occurs in segments that are highly incompatible with nasalization.

Walker's investigation focuses primarily on the supralaryngeal consonants: observe that glottal consonants are not mentioned as such in 15 (although see her discussion in §2.2.3). In principle, glottals could behave like any other consonant: the glottal fricative could behave like a fricative, and the glottal stop like any other plosive; but in fact their behavior generally differentiates them from the other consonants. (The unusual case of Tereno will be discussed below.)

3.1. PLACING GLOTTALS ON THE NASALIZATION HIERARCHY. The nasal harmonies of languages like Sundanese and Capanahua assist us in determining the placement of glottals in the nasalization hierarchy. In both of these languages, the glottal consonants occur within [nasal] spreading spans. Sundanese is thus an example of a language in which ONLY VOWELS AND GLOTTALS are permeated by nasal harmony, and Capanahua is an example of a language in which VOWELS, GLOTTALS, AND SEMIVOWELS are permeable by nasalization. Ranking glottals towards the high end of the nasal compatibility hierarchy, either with the vowels, or between the vowels and the semivowels, is consistent with their patterning in these languages, where glottals are permeated by nasal harmony along with the high-ranked vocoidal segments. This placement predicts that glottals should rarely if ever block nasalization, and this seems to be correct (see surveys discussed by Cohn 1993a, b, Walker 1998). In contrast, positioning glottals near the opposite end of the nasalization hierarchy wrongly predicts they would block harmony in Sundanese and Capanahua, because glottals would be ranked lower in compatibility than the consonantal segments that block spreading in the language. Further, with a low (rightward) placement, glottals are expected to most often block [nasal] spreading, and they should propagate nasality spreading only when all higher ranked segments in the hierarchy are permeated. These predictions are not borne out.

[12] There may be some variability across languages in the ranking of voiceless fricatives and voiced stops in the nasalization hierarchy; see Walker 1998:62 for an explanation of this variability.

[13] A long-distance nasal agreement pattern occurring in certain Bantu languages does not fall under this characterization (Ao 1991, Odden 1994, Hyman 1995, Piggott 1996). Walker (1998:§6.2) argues that these alternations are the result of cooccurrence restrictions, not [nasal] spreading.

Since it is only when glottals are analyzed as highly compatible with nasalization that we get the correct predictions about their behavior in nasal harmony, we propose that glottals should be situated toward the high compatibility end of the nasalization hierarchy. Most researchers agree with this finding: the hierarchical descriptions of nasalization proposed by Schourup 1972 and Piggott 1992 locate glottals between vowels and semivowels, and that is compatible with our observations.[14]

This relatively high placement of glottals in the nasalization hierarchy recognizes their relative permeability by nasalization. Yet permeable segments can be realized in one of two ways: nasal or oral. Walker found that the oral outcome arises only with segments that are highly incompatible with nasalization, i.e. segments ranked very low in the nasalization hierarchy. Given the high ranking of glottals, the expectation is that they are actually nasalized when permeated by nasalization, that is, within the set of permeable segments, they should be grouped with the targets, not the transparent segments. This is confirmed by our discussion in §§1-2 of the existence of nasalized glottals in [nasal] spreading patterns. There are thus good arguments for positing permeable glottals as targeted by nasal spreading and no reason to believe them to be transparent; in fact, positing glottals as transparent (i.e. skipped by [nasal] spreading) would run counter to the crosslinguistic generalizations we have established.

The phonetic basis for the high-ranked status of glottals in the hierarchy, at least in the case of glottal stops, is articulatory: a lowered velum is entirely compatible with the glottal articulation, as agreed upon by the many phoneticians cited earlier. However, the lack of perceptibility of a lowered velum during a glottal stop may have consequences for the role that a nasal glottal segment may play outside of [nasal] spreading. We take up this issue in §4.

3.2. CLAIMED COUNTEREXAMPLES. We have proposed that glottals should be situated between vowels and semivowels on the nasalization compatibility hierarchy. Cohn however, (1993b:166–67) cites six languages reported to have nasalization of just vowels and semivowels; these six (Arabela, Breton, Chinantec, Konkani, Maxakali and Urdu) appear to be counterexamples to a hierarchy positing glottals as invariably more likely to be nasalized than semivowels. In each case Cohn relies on secondary sources, and notes that the primary sources should be consulted to verify that the term glides is intended to exclude glottals. Returning to primary sources, we discovered in all six cases either that there is spreading through glottals or that no glottals occur in the relevant environments. In the case of Arabela one of the glottals even triggers nasal spreading (some additional attention is needed for Tereno, as we will explain below).

None of the six languages presents a case where semivowels are permeated by nasalization while glottals block it. Given this, and the large number of languages documented to have glottals permeable by spreading of nasalization (Schourup 1972, Piggott 1992, Cohn 1993b, Walker 1998), it is clear that the overwhelming crosslinguistic tendency is for glottals to be categorized phonologically as highly compatible with nasalization, i.e. in the vicinity of the vocoids. Following Piggott 1992 we will use the term LARYNGEALS to characterize this glidelike phonological classification of glottal segments. We will continue to use the term GLOTTAL to refer to the phonetic segments [ʔ] and [h] independent of their phonological patterning. Since there are cases where laryngeals are permeated by nasalization while semivowels block (e.g. Sundanese), we

[14] Cf. Cohn 1993a. Cohn argues that glottals should be located on a separate dimension from a nasalization hierarchy containing supralaryngeal segments.

place laryngeals between the vowels and semivowels in the nasalization hierarchy, consistent with the findings of Schourup and Piggott, as noted above, giving the revised hierarchy in 17.

(17) Vowels Laryngeals Semivowels Liquids Fricatives Obstruent Stops
← high———*compatibility with nasalization*———low →

Although the six languages cited above seem not to counterexemplify this hierarchy, it has been reported that in Tereno semivowels undergo nasalization and certain continuant segments pronounced as glottals block nasal spreading. Turning to this now, we present diachronic and synchronic evidence arguing that the glottal continuants are actually weak realizations of phonological obstruent fricatives.

In Tereno (Arawakan; Brazil), described by Bendor-Samuel (1960, 1966), nasalization is used to mark the first person inflection, such that nasalization starts at the beginning of the word and spreads progressively through sonorant segments, as in 18. Voiceless obstruents block [nasal] spreading but become voiced and prenasalized at the boundary of nasalization. This occurs even when the obstruent is word initial.

(18)	a. ajo	'his brother'	e. ãj̃õ	'my brother'
	b. owoku	'his house'	f. õw̃õ^{ŋ}gu	'my house'
	c. iso	'he hoed'	g. ĩ^{n}zo	'I hoed'
	d. piho	'he went'	h. ^{m}biho	'I went'

In this nasalization, the glottal stop behaves in the usual way: it does not block nasal spreading (see 19d), but segments normally realized as the glottal continuants [h] and [h^{j}] pattern with the voiceless obstruents in blocking nasalization spread. At a nasal span boundary, these segments are produced as voiced prenasalized alveolar and alveopalatal fricatives, respectively 19e-f.

(19)	a. emoʔo	'his word'	d. ẽmõʔ̃ũ	'my word'
	b. iha	'his name'	e. ĩ^{n}za	'my name'
	c. ah^{j}aʔaʃo	'he desires'	f. ã^{n}ʒaʔaʃo	'I desire'

In its failure to block nasality spreading, the glottal stop patterns as a laryngeal, that is, as a segment close to glides in its compatibility with nasalization. However, the behavior of [h] and [h^{j}] in Tereno indicates that their glottal realization is not diagnostic of their phonological status—they are grouped with the obstruent fricatives, a classification with which Bendor-Samuel (1960) agrees.[15] On the patterning of [h] with the supralaryngeal fricatives, Ohala (1983:208 drawing on Bendor-Samuel 1966, Noble 1965) points out that there is comparative evidence that at least some of the [h]'s in Tereno derive from an earlier apical obstruent [t]. Ohala and Ohala (1993:231) speculate that this [t] passed through an intermediate stage of [s] before becoming [h]. This hypothesis is strengthened by the [h, s] ~ [^{n}z], [h^{j}, ʃ] ~ [^{n}ʒ] alternations, showing that there is also synchronic support for the phonological classification of segments produced as glottal continuants with the fricatives, i.e. they are debuccalized or weak fricatives.

With this understanding of [h] and [h^{j}], the blocking behavior in Tereno remains consistent with the nasalization hierarchy. The set of blocking segments in Tereno consists of the fricatives (with supralaryngeal and glottal realizations) and obstruent stops. The remaining segments in the hierarchy make up the set permeated by nasalization; this includes the class of laryngeals, which in Tereno contains just [ʔ]. Our proposal

[15] In the case of [h^{j}] there is also a phonetic motivation for the fricative classification, since it is pronounced with 'friction produced with the passage of air through the gap between the blade of the tongue and the alveolar area' (Bendor-Samuel 1960:349).

is thus that the nasalization hierarchy itself remains fixed. What distinguishes glottal continuants in a language like Tereno from others is that although these segments are realized phonetically with glottal articulation, they correspond phonologically to voiceless obstruents, which are highly incompatible with nasalization,[16] rather than being grouped with the phonological class of laryngeals, which pattern more closely with semivowels.[17]

4. PHONEMIC NASAL GLOTTAL STOPS AND THE ISSUE OF PERCEPTIBILITY. A natural question to ask, given our defense of the possibility of glottal nasal stops, is whether they could also play a role as an underlying segment type. That possibility should not be ruled out, though there may seem to be an objection on the basis of perceptibility. Nasality is not audible in a glottal stop, which might in turn suggest a problem for learnability: if a language had a phonemic nasal glottal stop, how would the learner ever know?

This rhetorical question does not seem unanswerable to us. Sounds can be detected not only through their acoustic properties but also via the acoustic consequences of their effects on neighboring segments. A child in the language acquisition phase could easily discover that a glottal stop was nasal: all that would be necessary is an identifiable nasal spreading process in the language.

It is not difficult to envisage a language where data of this general character made it clear that the best phonology involved an underlying glottal nasal. Suppose we encountered a language in which the bilabial-initial syllable types were those in 20.

(20) pi pe pa po pu
mĩ mẽ mã mõ mũ

Suppose we then found that in the western dialect there were velar-initial syllables as in 21a, but in the eastern dialect these had shifted to glottal and nasality was retained so that we found the pattern in 21b.

(21) a. ki ke ka ko ku
ŋĩ ŋẽ ŋã ŋõ ŋũ
b. ʔi ʔe ʔa ʔo ʔu
ʔ̃ĩ ʔ̃ẽ ʔ̃ã ʔ̃õ ʔ̃ũ

On the basis of both synchronic and diachronic considerations, the eastern dialect could be plausibly analyzed as having an underlying glottal nasal stop.

Of course, no clear case of this sort has been documented. In an insightful examination of this issue, Ní Chiosáin and Padgett (1997) offer an explanation for the unattested nature of phonemic nasal glottals from the perspective of segmental contrast. Building on the dispersion-theoretic approach of Flemming (1995) and Cohn's observations on factors affecting compatibility of nasalization with glottals (1993a:361–63), they ob-

[16] An interesting alternative is suggested to us by Cohn. The Tereno data are consistent with a possible reanalysis of the segment produced as [h] as underlyingly an archiphoneme which is filled in either as [h] (in the general case) or as [s] (which is then voiced to [z] under nasalization). Under this account, [h] is never grouped with the obstruent fricatives, but [s] is.

[17] Rejang (Austronesian; South Sumatra) might present a second case of blocking by segments phonetically produced as glottals, following a report by McGinn (1979) that the glottal stop inhibits the progressive spread of nasalization. However, the glottal stop blocking has not been instrumentally verified, and Robert Blust (personal communication) notes that in his own field research with Rejang speakers he 'heard no oral vowels in nasalizing environments where a laryngeal consonant interceded'. These conflicting reports indicate that further investigation of the behavior of glottal stop in Rejang nasalization is necessary before its implications for the nasalization permeability hierarchy can be considered.

serve that two major factors enter into shaping a phonemic inventory, ARTICULATORY MARKEDNESS (i.e. relative difficulty of articulation) and PERCEPTUAL DISTINCTNESS between segments. Perceptual distinctness refers to the requirement that for two segments to contrast in an inventory, there must be some minimally perceptible acoustic difference between them, and the greater the perceived acoustic distance, the better the contrast. Applying these principles to the question of nasal glottals in inventories, Ní Chiosáin and Padgett point out that because there is no acoustic difference between [ʔ] and [ʔ̃], there can be no perceptual contrast between these segments. (This does not contradict our point that a phonological contrast could in principle be recoverable from a nasal versus oral vocalic context, but it does give reason for thinking such a development would be unlikely.) In constructing an inventory with a single glottal stop, Ní Chiosáin and Padgett suggest that articulatory markedness determines selection of the oral glottal rather than a nasal one, because the oral glottal is less articulatorily complex. In the context of nasalization permeating through a glottal stop, they point out that since there is no acoustic consequence to maintaining a lowered velum throughout the glottal, it will be nasalized. The alternative—to raise the velum during the glottal stop and then lower it again for the following segment—introduces needless articulatory difficulty. This accounts for the high-compatibility ranking of laryngeals in the nasalization hierarchy for [nasal] spreading. The principles of articulatory markedness and perceptual distinctness thus bring understanding both to the susceptibility of glottal stops to [nasal] spreading and to the rarity of nasal glottals in phonemic inventories.

5. CONCLUSION. We have examined the only case we are aware of in which it has been suggested that a pronounceable segment be excluded from phonology by a representational constraint, and found evidence to the contrary. We conclude that it is reasonable to assume that phonetically possible segments are always capable of being phonological units. Of course, there could be extraneous features that prevented certain contrasts from being sustainable in a phonological system; it may well be nonviable for a language to have both the bilabial nasal and the labiodental nasal as phonemes in one language, because acoustically the difference is too subtle. But one should be cautious about making such claims: Maddieson (1989) confirms the existence in Vanuatu of languages contrasting bilabial, linguo-labial, and alveolar nasals. We are raising a question that is independent of what constitutes a workable set of contrasts in a system: should some constraint be built into phonological description to render such things as labiodental nasals and nasal glottal stops phonologically impermissible despite their pronounceability?

At the very least, such a proposal would need to be argued for. The parsimonious position would be that phonetic possibility determines eligibility for occurrence in phonological descriptions. Constraints on contrast systems in phonology, as studied by Flemming (1995) and Ní Chiosáin and Padgett (1997), are a different matter; it is this component of the grammar that ensures that not every element of descriptive detail about the articulation of a segment will play a role in the phonological (or even phonetic) representation.[18] But for segments considered in isolation, our conclusions are as follows. Question 1a is still a matter of live current debate—a variety of cases give reason to speculate that phonology on occasion makes reference to combinations of feature specifications describing phonetically impossible segments. And with regard to 1b, we

[18] On the related subject of features that are attested but rare in the phonetic and phonological segments of the world's languages, see Ladefoged & Everett 1996.

think that phonologically permissible segments include all the phonetically possible ones.

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