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CHAPTER

The Limits of Phonetic Determinism in Phonology

***NC Revisited**

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I. INTRODUCTION

Virtually since the founding of modern phonology, there have been recurrent proposals for the incorporation of phonetic insights into phonological theory. Phonological rules frequently resemble phonetic processes, which in turn have natural explanations in the physiology, acoustics, and perception of speech. As numerous studies have shown (e.g., Wang & Fillmore, 1961; Chen, 1970; Ohala, 1974), the "seeds" of such phonological rules can be traced to the intrinsic variations in speech that become phonologized into the grammars of languages.¹ That "naturalness" is prized by many phonologists is, thus, not surprising. It is, however, surprising when individual phonologists insist that all phonology must be executed in phonetic terms: phonological rules must derive from phonetic principles, and whatever is not characterizable as phonetically determined is, thus, not phonology. According to this view, language-specific generalizations that appear to have no phonetic justification must be relegated to the morphology (e.g., as morpholexical rules) or are dismissed as historical residue that has simply to be listed in individual allomorphs. Others, standing opposed to phonetic determinism, deny that phonology need be constrained by phonetic considerations at all. Such scholars typically emphasize the formal and cognitive nature of (abstract) phonology as part of grammar versus the (concrete) phonetic substance from which phonological systems derive historically.²

All of this discussion essentially reduces to the basic question: what is the proper relation between phonetics and phonology? While addressed over and over in the history of modern linguistics, the question has recently returned to the fore with attempts to phoneticize Prince & Smolensky's (1993) Optimality Theory (OT). Prince & Smolensky propose that the diverse properties of phonological systems result from the different rankings of universal and violable constraints. In their implementation, developed further in McCarthy & Prince (1993, 1994) and elsewhere, these constraints are phonological, for example, MAX (don't delete), DEP (don't epenthesize), IDENT(I/O) (the input and output should be identical). In many cases, specific phonetic substance is the subject of a constraint. Pater (1996, 1999), for instance, proposes a constraint *NT that penalizes consonantal sequences of [+nasal] followed by [-voice].³ The effects of this constraint can be both distributional and processual. First, many languages have prenasalized voiced stops, but lack prenasalized voiceless stops. Second, as Pater shows, the relative high ranking of *NT accounts for the fact that the voiceless stop of a heteromorphemic N+T sequence is deleted in Malay, while the corresponding voiced stop of N+D sequences is not. Hayes (1995, 1997) further emphasizes the phonetic motivation of the frequent process by which obstruents become voiced after nasals, that is, NT → ND, whose effect is to respect Pater's constraint *NT. Both Hayes (1997, pp. 18–19) and Flemming (1995, p. 3) claim that an opposite,

counter-phonetic process, ND → NT, whereby an obstruent becomes devoiced after a nasal, is unattested. Hayes accounts for this by showing that *NT is "phonetically driven," while a corresponding constraint *ND, which would rule out a sequence of nasal+voiced stop, is not. On the assumption that phonological constraints must be phonetically driven, further developed in Kirchner (1998), there can be no constraint *ND, and, hence, it is claimed, no language that has postnasal devoicing.

I have two goals in this paper. First, I would like (once more) to address the general relation between phonetics and phonology. I will argue in section II that phonetic determinism ought not to be a synchronic principle, but rather is relevant only in the diachronic domain. As Ohala (1989, 1993) has argued in a number of publications, commonly occurring sound changes have the character they do because of their direct phonetic source. The same can be said about the phonetic naturalness of resulting phonological rules: "the reason natural rules are the way they are is that they are deeply grounded in the universal phonetic properties of speech" (Hyman 1975a, p. 171). The position argued below is that, once such natural phonetic processes are "phonologized," they enter into the realm of grammar and are subject to different principles.⁴

My second goal in section III is to reconsider Pater's *NT constraint, and particularly, the implications that Hayes draws from it. Citing Bantu examples, I shall provide evidence for the constraint *ND that "counter-balances" *NT. I shall show that postnasal devoicing does in fact occur, for example, in the Sotho-Tswana subgroup. I will demonstrate that a number of languages allow NT without allowing ND. I shall suggest that the reason these languages "prefer" NT over ND is perceptual. I then consider a number of other nasal+consonant processes to determine the role that perception may play in motivating such "counter-processes" as postnasal devoicing. I end with a brief conclusion in section IV.

II. THE PLACE OF PHONETICS IN PHONOLOGY

In this section, I consider the role of phonetics in phonology. I note first that there are at least four intuitive arguments for incorporating phonetics into phonology.

First, an "economy argument" is sometimes given: phonetics and phonology utilize a common alphabet. Both use descriptive terms such as "voiceless stops" and "nasalized vowels." As this argument goes, it would be more economical, therefore, to treat the two as one, meaning that phonology should be executed in phonetic terms, that is, phonology = phonetics.⁵

Second, there is no well-defined boundary between phonetics and phonology. In many cases it is at best difficult to determine whether a "low-level" process

is a post-lexical phonological process or part of the language-specific phonetics of a language.⁶

Third, phonetics is often “explanatory” of phonology. Given the goal of linguistics to be an explanatory science, it has seemed natural to incorporate “the explanation” directly into the formulation of grammar.⁷

Finally, it is at least implicit in much of this work that the phonetics can constrain phonology. Given the difficulty in developing a restrictive theory of phonology (or grammar in general), perhaps if we were to require that phonology must mimic phonetics we would be that much closer to determining what is possible within phonology.

For some or all these reasons, some phonologists propose to do phonology in increasingly phonetic terms. Flemming (1995), for instance, proposes various auditory constraints within OT that refer directly to formant structure. These, then, function directly in individual phonologies. In this way, as one gets closer to the raw material (and its auditory effect), the resultant phonologies should have a less arbitrary character, deriving in all cases from the ranking of universal phonetic constraints. As Hayes (1997, p. 14) puts it, “it is reasonable to suppose [. . .] that virtually all of segmental phonology [. . .] is driven by considerations of articulatory ease and perceptual distinctness.” On the other hand, we find opposing statements: “although phonological processes are expressed in phonetic terms, they do not have underlying phonetic motivations” (Kaye, 1989, p. 53). Kaye instead sees phonology as an aid to parsing. Rather than seeing phonology as “phonetically driven,” an opposing view is that it is computationally driven: “the phonology is a computational system that manipulates abstract categories and does not incorporate information about phonetic naturalness” (Buckley, 1999, p. 6). Similarly, Hale & Reiss (1998, pp. 6–7) “assume that the substance of phonological entities is never relevant to how they are treated by the computational system, except in *arbitrary, stipulative* ways” (their emphasis). According to Hale & Reiss, “Phonology is not and should not be grounded in phonetics since the facts which phonetic grounding is meant to explain can be derived without such grounding.”

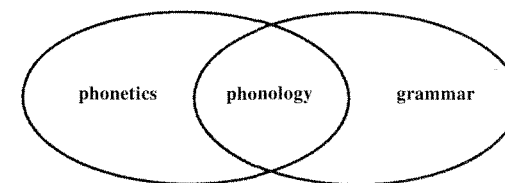
In order to sort out these issues, it is useful to reconsider two common dichotomies: phonetics vs. phonology and synchrony vs. diachrony.

A. Phonetics ≠ Phonology

The question at issue might be phrased as “how phonetic is phonology?” First, most scholars begin with the notion that there is a distinction. While phoneticians often have an interest in phonology (and phonologists often have an interest in phonetics), there are considerations of both subfields that more naturally interact

(or intersect) than others. If phonetics deals with the production, acoustics, and perception of speech sounds, then phonology can be defined as in (1):

(1) Phonology = “the intersection of phonetics and grammar”



As seen, I have represented phonetics and grammar as two large ellipses, the intersection of which is phonology. This meeting of speech sounds with grammar is what drives the distinction between phonetics and phonology.⁸

As an illustration of the need to view phonology as the intersection of phonetics and grammar, consider Ohala’s (1990) generalization concerning the creation of geminates by place assimilation. Ohala points out that, when place assimilation occurs in a heterorganic sequence of stops, C_1C_2 tends to become C_2C_2 , rather than C_1C_1 , for example, Latin *septem, *octo# > Italian sette, otto (not *seppe, *okko). Ohala’s explanation is that C_1 tends to be unreleased, hence less salient perceptually than C_2 , which, in the examples considered, is necessarily released into the following vowel. It is thus to be expected that the non-released C_1 will assimilate to the released C_2 , whose perceptual cues are more prominent, rather than the reverse. A similar explanation is offered to explain why homorganic nasal assimilation (HNA) results in changes such as /np, nt/ → [mp, nt] rather than *[nt, nk], where the stop assimilates to the place of the preceding nasal.⁹

While I agree with Ohala’s generalization and explanation for it, there are, however, important counterexamples to it. The one I shall cite here comes from the realization of the progressive suffix /-te/ in Noni, a Bantoid language spoken in Cameroon (Hyman, 1981). The relevant data are presented in (2).

(2) Realization of the progressive suffix in Noni

a.	cím	‘dig’	cim-tè	‘be digging’
	dvum	‘groan’	dvùm-tè	‘be groaning’
b.	bín	‘dance’	bin-è	‘be dancing’
	kfun	‘hit’	kfun-è	‘be hitting’
c.	cíŋ	‘tremble’	ciŋ-kè	‘be trembling’
	kán	‘fry’	kaŋ-kè	‘be frying’
d.	kéy	‘cough’	key-tè	‘be coughing’
	kfúy	‘trim’	kfuy-tè	‘be trimming’
e.	jíw	‘blacken’	jii-kè	‘be blackening’
	law	‘pay’	làà-kè	‘be paying’

f.	cii	'drag'	cii-lè	'be dragging'
	dɛɛ	'cook'	dɛɛ-lè	'be cooking'
g.	bi	'follow'	bi-i	'be following'
	tó	'itch'	to-ò	'be itching'

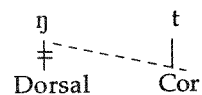
The forms in (2a) show that /-te/ is realized without change after a root-final /m/. In (2b) it can be seen that its /t/ drops out after the homorganic root-final consonant /n/. It is the examples in (2c) that interest us here: the input sequence /ŋ+t/ is realized [ŋk]. The /t/ has assimilated to the velar place of the preceding [ŋ]. The development of the prenasalized stop is accompanied by compensatory lengthening in presumably the same way as discussed by Tucker (1962) and Clements (1986) for (lu-)Ganda. In Noni, the only coda consonants allowed are nasals and glides. The forms in (2d-g) show how the progressive suffix is realized after all of the remaining monosyllabic root structures. In (2d) it is realized as -te, while in (2e) we see that it assimilates to the velarity of the preceding [w], which drops out, again producing compensatory lengthening. Finally, the progressive suffix is realized -le after a CVV root in (2f) and as vowel lengthening after CV roots in (2g).

Given the generality of Ohala's observation, the question is why the Noni progressive suffix works differently. I would like to suggest that Noni constitutes a principled counterexample that can be explained by reference to the view of phonology in (1). The reason why the [t] of the progressive suffix /-te/ assimilates to a preceding velar is that it is a suffix. Besides phonetic principles, phonology is subject to (possibly conflicting) grammatical ones. The relevant principle here is a paradigmatic one: languages frequently preserve base features over affixal ones. We know that affixal morphemes are frequently subject to greater reduction, for example, assimilation, than root morphemes. This has recently been expressed by McCarthy & Prince (1995) as "root faithfulness." What I would like to suggest is that, where root faithfulness is low ranked, Ohala's phonetic explanation will have maximal effect. However, where root faithfulness is ranked high, that is, higher than affix faithfulness, a Noni-like effect will instead occur.¹⁰

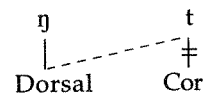
To summarize, Ohala claims in his study that the nasal of a heterorganic N+C sequence should assimilate to the following consonant, as seen in the informal feature geometric representation in (3a).

(3) Need for assimilations/autosegmental spreading in both directions:

a. standard HNA: /ŋt/ → [nt]



b. Noni: /ŋt/ → [ŋk]



As indicated, such right-to-left place assimilation aptly captures standard homorganic nasal assimilation. Ohala goes on, however, to say that the reverse process formulated in (3b) ought not to occur. He criticizes feature geometry for its ability to express the disfavored left-to-right place assimilation process indicated in (3b) as easily as the favored right-to-left HNA in (3a). However, this is exactly what is needed: the Noni example shows that an input sequence /ŋ+t/ may undergo place assimilation in either direction. In light of such counterexamples to Ohala's generalization, we are faced with two possible responses. The first response would be to say that Noni-type counterexamples are simply rare, that is, "marked" in phonological terminology. A more explanatory response would be to say that the Noni data constitute a principled counterexample that can be accounted for by reference to the grammatical (here, paradigmatic) side of phonology. The prediction we are left with is that rules such as (3b) should not readily occur unless motivated other than by perceptual phonetics.

As the above demonstrates, the bipolar view of phonology schematized in (1) can actually have the effect of saving phonetic generalizations that otherwise would be obscured if grammar were not simultaneously taken into consideration.

B. Diachronic Phonology ≠ Synchronic Phonology

The second dichotomy I would like to briefly consider is that between diachronic and synchronic phonology. As pointed out numerous times in the history of generative phonology — and despite frequent resemblances — the synchronic analysis of phonological systems is not equivalent to going through the historical changes that produced them. Phonological systems are the way they are not only because of the phonetic conditioning of sound changes, but also because of telescoping, restructuring (e.g., by analogy), and borrowing. The result can be quite "unnatural."

(4) Labial palatalization in Ndebele (Bantu; Zimbabwe) (cf. Sibanda, 1998)

	Active		Passive	
a.	boph-a	'tie'	boc-w-a	'be tied'
	vuβ-a	'mix together'	vuc'-w-a	'be mixed together'
	dob-a	'pick up'	doj-w-a	'be picked up'
	bumb-a	'mould'	bunj-w-a	'be moulded'
	thum-a	'send'	thuɲ-w-a	'be sent'
b.	dal-a	'create'	dal-w-a	'be created'
	thuk-a	'curse'	thuk-w-a	'be cursed'

	Active		Passive	
c.	fumbath-a	'clench (hand)'	funjath-w-a	'be clenched'
	vumbulul-a	'uncover, unearth'	vunjulul-w-a	'be uncovered'
	phambukis-a	'lead aside'	phanjukis-w-a	'be led aside'
	gombolozel-a	'encircle, surround'	gonjolozel-w-a	'be encircled'
d.	βal-a	'read'	βal-w-a	'be read'
	βik-a	'announce'	βik-w-a	'be announced'
e.	aphul-a	'break, snap off'	aphul-w-a	'be broken, snapped off'
	aβel-a	'share, allot to'	aβel-w-a	'be shared, allotted'
	amuk-a	'deprive, take away'	amuk-w-a	'be deprived, taken away'

As an example, consider the palatalization of labial consonants in southern Bantu languages, illustrated here in Ndebele (cf. Sibanda, 1998). As seen in (4a), the labial consonants /ph/, /β/, /b/, /mb/, and /m/ are realized, respectively, as c [tʃ], c' [tʃ'], j [dʒ], nj [ndʒ], and ɲ when followed by the passive suffix -w-, where c' = ejective. There are at least four reasons why Ndebele labial palatalization represents a synchronic restructuring.

First, the change of labials to palatals before [w] in (4a) is synchronically unnatural, the result of telescoped sound changes, that is, *Bwa > Bɥa > By(w)a > BJ(w)a > J(w)a (Tucker, 1929; Ohala, 1978), where B and J = labial vs. palatal consonants, respectively.¹¹ As often remarked (Ohala, 1978; Kawasaki, 1982; Flemming, 1995), sequences of labial + [w] are frequently missing, or, as we see here, modified so as to avoid such sequences. However, this observation cannot in itself predict why labials should become palatalized (with the [w] remaining), nor why /B/ should alternate with ejective [tʃ'].¹²

Second, as seen in (4b), only labials are affected by palatalization vs. the more usual palatalization of coronals and/or velars: "Palatalization is less easily introduced on labials than on dentals and velars; and if introduced, it is more easily lost" (Hock, 1991, p. 133). An alternation between [m] and [ɲ] has to be viewed as less "natural" than one between either [n] and [ɲ] or between [ŋ] and [ɲ].

Third, as seen in (4c), the labial/palatal alternations have been analogized to apply at-a-distance. In the examples cited, morpheme-internal /mb/ is realized [ndʒ] because of the passive suffix -w- with which it is not contiguous. Thus, even if we could rationalize the palatalization of labials in (4a) as a response to Flemming's (1995) auditory constraint *Bw, we would be hard put to explain how the putative phonetic constraint *Bw can have such a long-distance effect.

Finally, there is again a morphological consideration. As seen in (4d), root-initial labials are exempt from at-a-distance palatalization, an apparent case

of positional faithfulness (Beckman, 1997). The vowel-initial roots in (4e) in fact show that a following labial consonant also escapes palatalization (cf. Downing, 2000). The generalization thus appears to be that the first consonant of a root, if labial, is not palatalizable.¹³

It thus seems relatively clear that the present state of Ndebele labial palatalization has involved both the telescoping of several sound changes as well as the analogizing of palatalization to noncontiguous environments. The question, then, is whether it should be the concern of synchronic phonology to make the situation look more "natural," particularly from a phonetic deterministic point of view. I suggest that it isn't. In order to see why not, let us briefly contrast the goals of diachronic phonology with those of synchronic phonology.

The goals of diachronic phonology are threefold.

First, diachronic phonology seeks to determine where phonology comes from. The answer, largely, has been that it derives via phonologization, the process by which "natural," quasi-universal variations in the speech signal come to be part of the phonological system of a language (Hyman, 1977).

Second, diachronic phonology seeks to determine how phonology changes — while still remaining phonology. This means studying the processes of telescoping, rule inversion, and other forms of restructuring. As seen in the Ndebele case, this includes analogy.

Finally, the third goal of diachronic phonology is to determine where phonology goes, that is, how does phonology cease to be phonology — for example, via morphologization, lexicalization, paradigmatic leveling, and rule loss.

For most linguists, the goals of synchronic phonology are quite different.

First, synchronic phonology seeks to determine the universal properties of sound patterns in languages. The key question here is: "What is a possible phonology?"

Second, synchronic phonology seeks to determine what's going on in the heads of speakers with respect to sound patterns.

Given the different goals of diachronic and synchronic phonology, we can now return to the question of phonetic determinism in phonology. It is quite clear that the phonetics plays a major role in diachronic phonology. The crucial question is: does phonetically driven phonology help us with the above two synchronic goals?

With respect to the first goal, can the phonetics determine universal properties of phonological systems? That is, can the phonetics constrain phonology (limit the class of "possible phonologies")? I am interested here in considering whether the phonetics can rule out "impossible" phonologies. I attempt to show in section III that it does not. Because of the restructurings that take place, phonetic universals are readily violated in synchronic phonologies.

Second, do speakers “know” phonetics? Is their knowledge of phonology stored in phonetic terms? Whereas the preceding question asks whether the phonetics rules out certain phonological systems, this second question, instead, asks whether it is “better” from a learnability point of view for synchronic phonological rules to mimic the phonetics? The answer has never been convincingly demonstrated, experimentally or otherwise. The evidence from actually occurring historical developments seems, largely, to be negative. Aside from the fact that phonological rules begin their existence as “natural,” given the phonologization process, the rest of their history seems to be on a downward slide from the phonetic point of view. As frequently noted, phonologized processes are typically subject to subsequent developments, which include further modifications of the input and output segments, including the conditioning environments, which ultimately can be lost entirely. The results are familiar: opacity, morphologization, exceptionality, etc. If naturalness were such an important factor, synchronically, why do natural rules so readily become denaturalized?

What kind of evidence might one, then, seek to justify the view that phonetic naturalness is an important criterion in synchronic phonology? Most examples cited involve phonetically driven rule activation, which I have relegated to the phonologization process. At least two other types of evidence, however, might be sought. First, one might look for instances of phonetically driven rule inhibition, that is, situations where otherwise general phonological rules are blocked from applying just in case the result would constitute an “unnatural” output. The hypothetical example cited in Hyman (1975a, p. 181) is reproduced in (5).

(5)

- a. /papi/ → → [papə]
 b. /paki/ → [pači] (→ *pačə)

In (5a), final [i] reduces to schwa by rule. In (5b), final [i] palatalizes the preceding /k/ to [č]. Because of phonetically driven rule inhibition, final reduction of [i] to schwa is blocked — for then the palatalization rule would be rendered opaque. Such situations are highly restricted at best, and, where occurring, have a different explanation.¹⁴

A second type of evidence for phonetic naturalness might be termed phonetically driven rule loss. If non-naturalness represents a relative complexity in learnability, less natural phonological rules should be more readily (i.e., earlier) lost than more natural ones. The place to look would be paradigms that provide both natural and unnatural alternations in otherwise comparable environments. Such a situation exists in (lu-)Ganda and several Bantu languages spoken in the Lake Victoria area. As seen in (6),

(6) Illustration from Ganda showing the neutralization of *p, *t, *k > [s] and *b, *d, *g > [z]

Proto-Bantu			Ganda	Correspondence	
a. *-p{dá	‘pus’	>	(ma)-síra	‘pus’	*p > s
*-kap{	‘oar’	>	(n)-kasí	‘oar’	*p > s
*-b{ń-	‘dance (v.)’	>	-zín-a	‘dance (v.)’	*b > z
*-b{mb-	‘swell (v.)’	>	-zím-b-a	‘swell (v.)’	*b > z
b. *-t{d-	‘rub, grind’	>	-sil-a	‘rub, pulverize’	*t > s
*-d{m-	‘extinguish’	>	-zím-a	‘extinguish’	*d > z
c. *-k{d-	‘be silent’	>	-sílik-a	‘be silent’	*k > s
*-g{d-	‘be taboo’	>	-zil-a	‘be taboo’	*g > z

Ganda underwent a series of consonant changes whereby tautomorphic stops ultimately became fricatives before Proto-Bantu tense *j: *p, *t, *k > [s], while *b, *d, *g > [z]. The alternations in (7) show that root-final alveolar and velar stops continue to undergo these “frications” synchronically when followed by one of the three indicated suffixes reconstructed with *j:

(7) Frication of *t, *d, *k, and *g before causative *-j-, agentive *-j-, and perfective *-jd-e

a. *-déet-j-	‘bring’ + -j-	>	-lées-j-	‘make bring’	*t > s
*-ded-j-	‘care for’ + -j-	>	-lez-j-	‘make care for’	*d > z
*-jjduk-j-	‘run’ + -j-	>	-‘ddus-j-	‘make run’	*k > s
*-jig-j-	‘learn’ + -j-	>	-yiz-j-	‘make learn’	*g > z
b. *-déet-j	‘bring’ + j	>	mu-lées-j	‘bringer’ (rain)	*t > s
*-ded-j	‘care for’ + j	>	mu-lez-j	‘caretaker’	*d > z
*-jjduk-j	‘run’ + j	>	mú-ddus-j	‘fugitive’	*k > s
*-jig-j	‘learn’ + j	>	mu-yiz-j	‘apprentice’	*g > z
c. *-déet-j	‘bring’ + jd-e	>	-lées-j	‘brought’	*t > s
*-ded-j	‘care for’ + jd-e	>	-lez-j-e	‘cared for’	*d > z
*-jjduk-j	‘run’ + jd-e	>	-‘ddus-j-e	‘ran’	*k > s
*-jig-j	‘learn’ + jd-e	>	-yiz-j-e	‘learned’	*g > z

On the other hand, the forms in (8) show that the labials *p and *b do not fricate before these suffixes:

(8) Non-frication of *p, *b before causative *-j-, agentive *-j-, or perfective *-jd-e

a.	*-puup-j-	'blow' + -j-	>	-puuy-j-	'make blow'	*p > w > y ¹⁵
	*-djb-	'fish' + -j-	>	-vub-j-	'make beat'	*b > b
b.	*-puup-j	'blow' + j	>	mu-puuy-j	'horn-blower'	*p > w > y
	*-djb-j	'fish' + j	>	mu-vub-j	'fisherman'	*b > b
c.	*-puup-j	'pay' + jd-e	>	puuy-j-e	'blew'	*p > w > y
	*-djb-	'fish' + jd-e	>	vub-j-e	'fished'	*b > b

Recall from (6) that labials, alveolars, and velars all become fricated tautomorphemically before *j. So, why should it only be the labials that do not alternate before the suffixes in question?

One hypothesis that can be considered here is that it has to do with the relative naturalness of the three alternations. Arguably, alternations such as p/s and b/z are less natural than either t/s and d/z or k/s and g/z. Both spirantization of alveolars and "velar softening" are well known to phonologists. Alternations of p/s and b/z seem more restricted (although known particularly to Africanists). Could it be that Ganda originally underwent these frications across the board, but that the heteromorphemic p/s and b/z alternations were leveled out specifically because they represented less natural relations between segments? Again, this is a question that has not been resolved. Do such considerations of naturalness play a role in suppressing synchronic alternations — that is, ultimately rule curtailment and loss? I believe the case is not strong here either.¹⁶

C. Summary

I have thus far argued, first, that phonology should be viewed as the intersection of phonetics and grammar (§II.A) and, second, that one should be careful to distinguish synchronic and diachronic phonology (§II.B). In this last regard, one has to be careful not to fall into the alluring trap of confusing the goals of synchronic vs. diachronic phonology or the difference between transparent phonologization vs. what we might call "mature phonology." Much of the discussion on phoneticizing phonology slips into this "trap." Recall Ohala's (1990) position on place assimilation in the creation of geminates and homorganic nasal+consonant sequences. Ohala begins by observing, first, that some phonologizations are unidirectional, and second, that current models of phonology are inadequate to capture this unidirectionality. Thus, a sequence such as V₁ntV could develop into VntV, but not into *V₁nkV. He points out that, because feature geometry can just as easily express both the attested as well as the allegedly

unattested (or rare) changes, as we saw in (3a) vs. (3b), it and other formal theories should be rejected on this basis.¹⁷ However, we have seen that the phonetic tendency in question can be overridden by other considerations, for example, the ranking of morphological constraints: Root Faithfulness > Affix Faithfulness. In other words, the explanation of the tendency noted by Ohala is not a synchronic phonological one, but rather a diachronic phonetic one. Rather than deploring feature geometry's ability to express (3b), its proponents may take comfort that feature geometry, a *phonological* framework, can still formulate the rarer alternation.

What I conclude from the above discussion is the following:

- i. Although there is much of phonology that is not phonetically arbitrary, there is little evidence that this is more than the consequence of the phonologization process: universal phonetics determines in large part what will become a language-specific phonetic property, which ultimately can be phonologized to become a structured, rule-governed part of the grammar.
- ii. Once part of the grammar, phonology may be further subjected to structural or systemic principles. What has been phonologized is thus often telescoped, analogized to broader contexts, subject to rule inversion, and/or morphologized.
- iii. It is possible to get relatively "unnatural" synchronic systems as a result of the interactions of "natural" processes.

In the next section, I return to Pater's (1996) constraint *NT, which Hayes (1995, 1997) has invoked in support of phonetically driven phonology. I will show that this constraint, although "phonetically grounded," does not get us closer to the two goals of synchronic phonology cited earlier: it neither constrains the class of possible phonologies, nor does it help us understand cognitive aspects of phonology, for example, what is going on in the heads of Sotho-Tswana speakers.

III. NASAL+OBSTRUENT INTERACTIONS

In this section I apply the conclusions of section II to the study of nasal+obstruent (N+C) sequences, particularly as they are realized in Bantu languages. Surveys

such as Herbert (1986), Rosenthal (1989), Steriade (1993), and others show a wide array of “natural” sound changes/resulting phonological rules affecting input N+C sequences. In what follows I shall use the following abbreviations:

(9)

N = nasal consonant	S = voiceless fricative
C = (oral) obstruent	Z = voiced fricative
T = voiceless stop	TS = voiceless affricate
D = voiced stop	DZ = voiced affricate

Based on their distribution, as well as the processes that affect them, the following hierarchy has been assumed, where \supset can be read either as “is better than” or “is implied by the presence of”:¹⁸

(10)

ND \supset NZ \supset NT \supset NS

As seen, the most “natural” combination of nasal+obstruent is ND. Many languages permit only ND (i.e., disallowing lower combinations in the hierarchy), either in their underlying system and/or in the phonetic output. Others generalize the system to include ND and NZ, while still others allow ND, NZ, and NT, disallowing only NS. Both these distributional generalizations and the recurrent processes that affect nasal+obstruents have “natural” phonetic explanations (e.g., Ohala, 1975; Ohala & Ohala, 1993; Hayes, 1995, 1997; Huffman & Hinnebusch, 1998). In addition, most of these generalizations apply equally well whether the N+C sequences are: (i) prenasalized consonants (NC); (ii) tautosyllabic sequences (.NC); or (iii) heterosyllabic sequences (N.C). As the above studies indicate, N+C realizations provide a wealth of data for the study of the phonetics–phonology interface.

A. Postnasal Voicing

In this section, I consider the voicing of obstruents after nasals, that is, NT \rightarrow ND. As stated by Herbert (1986, p. 236), “Perhaps the most common process to apply to the oral consonant in nasal–oral sequence is postnasal voicing of voiceless consonants.” In fact, of all environments, the postnasal context appears to have the greatest effect on voicing: “A healthy supply of languages voice obstruents after nasals, but not after vowels, glides, or liquids” (Hayes, 1995, p. 2). As an example, consider in (11) the data from (ci-)Yao, a Bantu language spoken in Mozambique and parts of Tanzania and Malawi:

(11) Yao postnasal voicing (Hyman & Ngunga, 1997; Ngunga, 2000)

- a. When the following consonant is voiceless, it becomes [+voice]
- | | | | |
|-------------|---------------|--------------|------------------|
| ku-N-péleka | \rightarrow | kuu-m-béleka | ‘to send me’ |
| ku-N-túma | \rightarrow | kuu-n-dúma | ‘to order me’ |
| ku-N-cápila | \rightarrow | kuu-ŋ-jápila | ‘to wash for me’ |
| ku-N-kwéela | \rightarrow | kuu-ŋ-gwéela | ‘to climb on me’ |
- b. When the following consonant is voiced, it deletes
- | | | | |
|---------------|---------------|--------------|-------------------------------|
| ku-N-búúčila | \rightarrow | kuu-múúčila | ‘to be angry with me’ |
| ku-N-lápa | \rightarrow | kuu-nápa | ‘to admire me’ |
| ku-N-jiíma | \rightarrow | kuu-ŋíma | ‘to begrudge me’ |
| ku-N-góneka | \rightarrow | kuu-ŋóneka | ‘to make me sleep’ |
| ku-N-mála | \rightarrow | kuu-mála | ‘to finish me’ |
| ku-N-néma | \rightarrow | kuu-néma | ‘for me to do incorrectly’ |
| ku-N-nála | \rightarrow | kuu-ŋála | ‘to cut me into small pieces’ |
| ku-N-ŋáándila | \rightarrow | kuu-ŋáándila | ‘to play around with me’ |
- c. An exception to the preceding is /d/, which does not delete
- | | | | |
|-------------|---------------|--------------|-----------------------|
| ku-N-dípa | \rightarrow | kuu-n-dípa | ‘to pay me’ |
| ku-N-délela | \rightarrow | kuu-n-délela | ‘to underestimate me’ |
- d. The nasal deletes when followed by /s/ (=the only voiceless fricative)
- | | | | |
|------------|---------------|-----------|------------------|
| ku-n-sóosa | \rightarrow | kuu-sóosa | ‘to look for me’ |
|------------|---------------|-----------|------------------|

As seen in (11a), voiceless stops become voiced after the first person singular prefix N-.¹⁹ This same rule applies in a number of other Bantu languages, for example, Kikuyu, (ki-)Nande, and Bukusu, where the output voiced consonants merge with the corresponding underlying voiced consonants. As seen in (11b), however, there is no such merger in Yao. Instead, voiced consonants delete after the nasal prefix — thereby neutralizing /b, l, j, g/ with /m, n, ŋ, ɲ/. As seen in (11c), the one exception to this deletion process is /d/. Finally, (11d) shows the common process of nasal effacement before the voiceless fricative /s/.²⁰ In all cases the vowel that precedes an input NC is lengthened.

The alternations in (11a) could be multiplied by quite a number of other Bantu languages in support of the claim that postnasal voicing is a natural phonological rule. As Pater (1996) and Hayes (1995, 1997) suggest, it is best seen as an active response to the constraint *NT. That is, a common means by which languages avoid NT is by voicing the oral consonant.

A second, *passive* response to *NT comes from potential cases where an otherwise general rule is blocked from applying just in case the result would be NT. Such cases are rare, one possible instance being the following from Basaá, a Bantu language spoken in Cameroon.²¹ Ignoring affricates, the stop system of Basaá is presented in (12), as realized in three different environments:

(12) Basaá stop system

a. stem-initial	b. phrase-final	c. elsewhere
p t k	p t k	b d g
mb nd ŋg	mb nd ŋg	mb nd ŋg

As seen, the Basaá oral stops /p, t, k/ are realized voiceless in both stem-initial and phrase-final positions. Examples are seen in (13).

(13)

a. li-pàn 'forest'	b. li-yép 'poverty'	(li- = class 5 prefix)
li-tám 'fruit'	li-yót 'anger'	
li-kùŋ 'owl'	li-ləik 'dancing'	

In other environments these stops are realized voiced, for example, in prefixes, as seen in (14a), or phrase-internally, as in (14b).²²

(14)

a. bi-jék 'food' (cl. 8)	b. li-yéb lí mût 'poverty of a person'
di-nuní 'birds' (cl. 13)	li-yód lí mût 'anger of a person'
	li-lóg lí mût 'dancing of a person'

As also indicated in (12), however, the prenasalized stops /mb, nd, ŋg/ appear as voiced in the same three environments. Crucially, postnasal voicing is maintained in the two devoicing environments, stem-initial (15a) and phrase-final (15b).

(15) Stem-initial and phrase-final ND

a. li-mbóó 'kind'	b. li-ùmb 'alcohol'
li-ndám 'round basket'	li-pènd 'barrier'
li-ŋgén 'fountain'	li-séŋg 'parasol-holder'

While one might attribute the non-devoicing of ND in (15a) to the fact that the N is stem-initial, not the D, this will not work in (15b), where it is the D that stands at the end of the phrase. This suggests that the universal tendency that prenasalized stops be voiced takes precedence over both the language-specific constraint that stem-initial stops be voiceless and the universal tendency for phrase-final obstruents to devoice.²³ In OT terms, the correct output is derived by ranking *NT higher than Final Devoicing, as in (16a).

(16) Basaá

a.	/ùmb/	*NT	FinDev
☐	ùmb		*
	ùmp	*!	

Non-Basaá

b.	/ùmb/	FinDev	*NT
	ùmb	*!	
●	ùmp		*

Had Final Devoicing been ranked higher than *NT, as in (16b), the incorrect output *ùmp would have been obtained.

B. Postnasal Devoicing

Taken together, the Yao & Basaá data show how *NT can either motivate a change of NT to ND, or inhibit a change of ND to NT. We are safe in concluding, along with others before us, that the postnasal environment is particularly conducive to voicing. On the other hand, the reverse rule, ND → NT, would be quite "un-phonetic" according to Flemming (1995, p. 3) and Hayes (1997, p. 18), who hypothesize that it is "rare or unattested." Similarly, we should not expect an otherwise general voicing rule to be inhibited by a preceding nasal.

However, postnasal devoicing is attested in Bantu, particularly in the Sotho-Tswana group and closely related Makua (Janson, 1991/1992), as well as in Bubi and certain other languages in the northwest Bantu area. In this section, I shall document postnasal devoicing in Tswana, where, I shall claim, there is a need for a constraint *ND that is higher ranked than Pater's *NT.

I begin by presenting the Tswana consonant system in (17), based on Krüger & Snyman (n.d., pp. 80–81):

(17) Tswana consonant system

p'	t'	k'		voiceless ejective stops
p ^h	t ^h	k ^h		voiceless aspirated stops
b	(d)			voiced stops (re [d], see below)
	t'			ejective voiceless lateral affricate
	t ^h			aspirated voiceless lateral affricate
	ts'	tʃ'		ejective voiceless affricates
	ts ^h	tʃ ^h	kx ^h	aspirated voiceless affricates
ϕ	s	ʃ	x	voiceless fricatives
	r			voiceless resonants
w	l	y	h	voiced resonants
m	n	ɲ	ŋ	voiced nasals

Shown above are the consonants of Tswana minus cases of NC, discussed below. Of concern to us are the voiced stops. As seen in (18), these devoice after the same first person singular object prefix N- exemplified in Yao in (11) above.²⁴

(18) Devoicing after 1 sg. object prefix N-

a. bón-á 'see'	b. m-pón-á 'see me!'
dís-á 'watch'	n-tís-á 'watch me!'
áráb-á 'answer'	ŋ-káráb-á 'answer me!' (< -gáráb-)

While the devoicing of m+b and n+d to [mp] and [nt] in (18b) is straightforward in the first two examples, the last example shows an alternation between the lack of a consonant in [áráb-á] and the [k] in [N-káráb-á]. As indicated to the right, however, such forms originally began with *g, which also devoiced after the nasal prefix, as seen.

Postnasal devoicing is, in fact, quite general in Tswana. The data in (19a) show devoicing after the class 9/10 prefix N- (PB = Proto-Bantu):

(19) Devoicing after class 9, 10 prefix N-

a.	n-tá	'louse'	PB	*n-dá
	n-twa	'battle, war'	PB	*n-du-a (cf. *-du-a > lw-a 'to fight')
b.	pútsó	'question'	cf.	bótsó 'to ask'
	/n-bots-o/			le-bóts-í 'interrogative'
	tiro	'work, deed'	cf.	dir-a 'to work, to do'
	/n-dir-o/			mo-dir-i 'worker'
c.	lo-bú	'salty terrain'	pl.	dí-m-pú
	lo-dí	'twine, bark string'	pl.	dí-n-tí [tone not indicated]
d.	lo-bone	'lamp'	pl.	dí-pone < dí-m-bone
	lo-eto	'trip'	pl.	dí-keto < dí-ŋ-geto
	lo-úpá	'ashes'	pl.	dí-kúpá < dí-ŋ-gúpá

When the noun roots are monosyllabic, as they are in (19a), the nasal both devoices the following consonant and remains. When the roots are longer, as in (19b), the nasal, which is present structurally and is responsible for the devoicing, drops out by rule.²⁵ Thus, the roots of the nouns *pútsó* 'question' and *tiro* 'deed', underlyingly /n-bots-o/ and /n-dir-o/, are realized with initial [b] and [d] in the related forms to the right. The remaining data involve a class 11 singular prefix lo-, which is replaced in the plural by the complex class 10 prefix *dí-N-*. In the plurals in (19c) the nasal devoicing the following consonant (and remains, since the noun roots are monosyllabic). The same devoicing is observed in the plurals in (19d), where, however, the nasal drops out, since the roots are bisyllabic.

Finally, note in (20) that the same postnasal devoicing occurred historically within roots, where there is no possibility of alternation:

(20) Historical postnasal devoicing + nasal loss within morphemes

a.	PB	*-bumb-	'mould, create'	>	Tsw.	-búp-	'mould, create'
b.	PB	*-gend-	'walk, go'	>	Tsw.	-et-	'travel'
c.	PB	*-teŋg-	'buy'	>	Tsw.	-rék-	'buy'

To summarize thus far, it should be clear that Tswana has a rule of postnasal devoicing, the exact opposite of the more widespread rule of postnasal voicing. According to the demonstrations in Hayes (1995, 1997), such a phonetically

unnatural rule is not supposed to exist. Someone wishing to dismiss the above evidence might therefore respond by attempting to relegate devoicing after N- prefixes to the morphology, thereby sparing the phonology of the need to account for the alternations via phonetically driven constraints.²⁶ The problem I see with this move is that it is typically opportunistic, that is, taken only when needed.²⁷ Many studies that have reported on the phonetic motivations of phonological rules have not bothered to distinguish whether the rules cited have a morphological character or not.

In fact, it is difficult to dismiss postnasal devoicing as simply a morphological issue (or, worse, as "historical residue"). The same scholars who argue for the phoneticization of phonology, for example, Flemming (1995), consider as part of their charge to account for static distributions within words and morphemes. With this in mind, consider the following table of distributions of NC in Tswana, based on Creissel's (1996) lexicon of ca. 5700 entries:

(21) Distribution of NC in Tswana, based on Creissels (1996)

	mp	mph	mb	nt	nth	nd	nd̥	ndh	nts	ntsh	ŋk	ŋkb	ŋg
C ₁	5	3	–	1	–	–	4	2	10	4	8	–	–
C ₂	22	2	2	21	1	–	8	3	5	14	16	–	–
C ₃	4	–	–	3	2	–	7	–	2	8	4	–	–
C ₄	–	–	–	5	–	–	–	–	–	–	–	–	–

Exceptions: *ámíbúlénsí* 'ambulance'; *bámíbáŋèxà* 'gratter fort'

The distribution of NC in all positions of stems up to four syllables (C₁VC₂VC₃VC₄V) were investigated, not counting the nasal, which is itself syllabic. As seen, only two exceptional forms were found that had ND, one of which is clearly a recent borrowing.²⁸ What is then in need of explanation is why Tswana has [b] and [d], but not [mb] and [nd]. I maintain that it is because of an active constraint *ND.

The two pieces of evidence adduced thus far in favor a constraint *ND are, first, that it would motivate postnasal devoicing and, second, that it would account for the absence of phonetic ND anywhere in the Tswana lexicon. A third argument is also quite telling. The proposed constraint *ND has the properties of a classic "conspiracy" (Kisseberth, 1970). We see this in two situations where ND is avoided not by postnasal devoicing, but by postnasal nasalization:

(i) The [u] of the various *mú-* prefixes in the language obligatorily deletes before a root-initial /b/. In principle, when [u] deletes, /mú+b/ should become [mb]. As seen in (22), however, /mú+b/ → [mm] (not *mb):

(22) $m\bar{u}+b \rightarrow mm$ (where $m\bar{u}-$ is a prefix)

a.	class 1	$m\bar{u}-b\acute{u}s-\acute{f}$	\rightarrow	$m-m\acute{u}s-\acute{f}$	'governor'	cf. $b\acute{u}s-\acute{a}$	'to govern'
	class 3	$m\bar{u}-b\acute{u}s-\acute{o}$	\rightarrow	$m-m\acute{u}s-\acute{o}$	'government'		
	class 1 object	$m\bar{u}-b\acute{u}s-\acute{e}$	\rightarrow	$m-m\acute{u}s-\acute{e}$	'govern him!'		
b.	class 3	$m\bar{u}-b\acute{u}tl\acute{a}$	\rightarrow	$m-m\acute{u}tl\acute{a}$	'hare'	cf. $m\bar{u}-b\acute{u}tl\acute{a}$	(pl.)
c.	class 1 object	$m\bar{u}-b\acute{o}n-\acute{e}$	\rightarrow	$m-m\acute{o}n-\acute{e}$	'see him!'	cf. $b\acute{o}n-\acute{a}$	'see'
		$m\bar{u}-b\acute{i}ts-\acute{e}$	\rightarrow	$m-m\acute{i}ts-\acute{e}$	'call him!'	$b\acute{i}ts-\acute{a}$	'call'

These examples show the deletion of the [u] of three different $m\bar{u}-$ prefixes: noun class 1, noun class 3, and the class 1 object prefix. Related forms are provided to show that the root-initial consonant is indeed /b/. Recall that \bar{u} -deletion is obligatory when the root-initial consonant is /b/, and does not apply when the following consonant is non-labial.²⁹

(ii) The second situation in which ND is avoided by postnasal nasalization concerns the perfective suffix *-ile*, illustrated in (23a).

(23) $n+l (\rightarrow n+d) \rightarrow nn$ in forming the perfective stem with the suffix *-ile*

a.	regular	$r\acute{e}k-\acute{a}$	'buy'	\rightarrow	$r\acute{e}k-ile$		
		$ts\acute{o}m-\acute{a}$	'hunt'	\rightarrow	$ts\acute{o}m-ile$		
b.	CVn-	$xan-a$	'refuse'	\rightarrow	$xan-ile$	\rightarrow	$xan-n-e$ (Cole, 1955/1992, p. 227)
		$non-a$	'be fat'	\rightarrow	$non-ile$	\rightarrow	$non-n-e$
		$men-a$	'fold'	\rightarrow	$men-ile$	\rightarrow	$men-n-e$
		$bin-a$	'dance'	\rightarrow	$bin-ile$	\rightarrow	$bin-n-e$
c.	Lobedu	$han-a$	'refuse'	\rightarrow	$han-ile$	\rightarrow	$han-\underset{\cdot}{d}-e$ (Kotze, 1998, p. 16)
		$non-ile$	'be fat'	\rightarrow	$non-ile$	\rightarrow	$non-\underset{\cdot}{d}-e$
		$vun-a$	'harvest'	\rightarrow	$vun-ile$	\rightarrow	$vun-\underset{\cdot}{d}-e$

As seen in (23b), the [i] of this suffix deletes after (monosyllabic) CVn-roots. However, the result is CVn-ne, not *CVn-de, as we would expect from other Bantu languages. One can see the relevance of the constraint *ND by considering comparable forms in Lobedu, an outlying northern Sotho dialect. As Kotze (1998) shows, this dialect in the Sotho-Tswana subgroup was not affected by postnasal devoicing. Therefore, as seen in (23c), when the [i] of the *-ile* perfective suffix is deleted, its /l/ hardens as (dental) [d̥]. As Dickens (1977, p. 165) shows, [d̥] is the regular reflex of *nd in Lobedu.³⁰

My interpretation of both sets of facts is that *ND functions as a conspiracy: when the deletion of the [u] of $m\bar{u}-$ prefixes threatens to produce [mb], and the deletion of the [i] of the *-ile* perfective suffix threatens to produce [nd], *ND enters into the picture and guarantees that this will not occur. The conspiratorial nature of *ND is shown by the fact that Tswana has two ways of avoiding ND: postnasal devoicing and postnasal nasalization.³¹

C. Why Postnasal Devoicing?

The most straightforward conclusion to draw from the preceding, therefore, is that Tswana requires the constraint *ND. What I would like to suggest is that *ND exists in other languages, but is normally ranked below *NT, as seen in (24a).

(24) The constraint *ND may be ranked below or above *NT

a. "normal"

	/m-bona/	*NT	*ND
☞	m-bona		*
	m-pona	*!	

b. Sotho-Tswana

	/m-bona/	*ND	*NT
	m-bona	*!	
☞	m-pona		*

As was seen in section III.A, the potential effect of *NT in such languages is to condition (or protect) postnasal voicing. In most Sotho-Tswana dialects, however, the ranking is reversed, as in (24b), and, as indicated, the effect is postnasal devoicing.

The Tswana situation raises two important questions:

(i) Is *ND phonetically "grounded" in the sense of Archangeli & Pulleyblank (1994)? Hayes (1997, pp. 17–18) suggests that it is among those rare or non-attested constraints that are not phonetically driven (in his terminology). If, on the other hand, *ND is available as a universal, but violable constraint — and if all such constraints must be phonetically driven — what is the elusive phonetic motivation that drives *ND? One cannot help noting that the output of postnasal devoicing is (variably) ejective. Perhaps postnasal ejectives are favored in some way that makes NT' "better" than NT. It is not clear, however, that NT' represents an improvement over ND. On the other hand, if we reject phonetic determinism as a criterion in synchronic phonology, we can simply draw the conclusion that *ND is an actually occurring constraint, as in Tswana.

(ii) The second question, then, is why Tswana should be different from other languages. I take this to be not a synchronic question, but rather a diachronic one: how did *ND come to outrank *NT, historically? It is this second question that I would like now to consider.

In (25), based on such sources as Tucker (1929), Dickens (1977, 1984), Krüger & Snyman (n.d.), and Creissels (1999), I show the correspondences between Proto-Bantu stops and early Sotho-Tswana:

(25) Sound correspondences between Proto-Bantu and early Sotho-Tswana

		N __	Elsewhere			N __	Elsewhere		
a.	*p	>	p ^h	ϕ	b.	*b	>	b	β
	*t	>	t ^h	r		*d	>	d	l (-[ɾ])
	*k	>	k ^h , kx ^h	h, x ³²		*g	>	g	ɣ (> Ø)

Two environments are distinguished: the postnasal environment is shown in the first column, while the second column represents the realization of the Proto-Bantu consonants in other contexts. Several observations should be made. First, concerning the proto system, some scholars begin instead with Proto-Bantu aspirated stops, that is, *p^h, *t^h, *k^h, and/or with Proto-Bantu voiced continuants, that is, *β, *l, *ɣ (Meinhof, 1932). The choice of proto system does not seriously affect the historical analysis. Either way, we see in (25a) that the voiceless series is realized as aspirated after a nasal, but as voiceless continuants in other environments.³³ As a result, present-day Tswana also has alternations between voiceless continuants and aspirated stops such as in (26).

(26)

a.	ϕeɲ-a	'conquer'	b.	m-p ^h eɲ-a	'conquer me!'
	rát-á	'love'		n-t ^h át-á	'love me!'
	xát-á	'trample'		ɲ-kx ^h át-á	'trample me!'

Returning to (25b), in early Sotho-Tswana, the proto voiced consonants were stops postnasally, but continuants elsewhere. At this stage *b was pronounced [β] and *g was pronounced [ɣ] (which subsequently dropped out). The alveolar continuant [l] had the allophone [ɾ], a retroflex flap, before the high tense vowels *i and *u.

With this background, we can now account for the rise of *ND in the following way. The devoicing of *mb, *nd, *ɲg to mp, nt, ɲk (with potential loss of the nasal) can be seen as the result of a prohibition against voiced stops in general in early Sotho-Tswana. In other words, with *b, *d, *g pronounced as continuants when not postnasal, the subsequent devoicing of voiced stops can be seen, historically, as context-free: *b, *d, *g > p, t, k. Compare Dickens's (1984) view, who assumes proto *β, *l, *ɣ and sees postnasal devoicing as the result of two distinct processes: "stopping, which converted voiced continuants (fricatives and l) into non-continuants after a nasal, for example, m+βona → mbona 'see me' (lit. me+see). [. . .] devoicing, whereby voiced non-continuants (the outputs of stopping) became voiceless and sometimes ejected, after a [. . .] nasal, for example, mbona → mpona 'see me'" (p.97).³⁴

A summary of the historical development of the Sotho-Tswana consonant system is given in (27).

(27) Historical stages involved in postnasal devoicing

		non-postnasal	postnasal	
a.	Stage I	*p, *t, *k *b, *d, *g	*mp, *nt, *ɲk *mb, *nd, *ɲg	(Proto-Bantu)
b.	Stage II	ϕ, r, x β, l ~ ɾ, ɣ	mp ^h , nt ^h , ɲkx ^h mb, nd, ɲg	(spirantization; aspiration ³⁵)
c.	Stage III	ϕ, r, x β, l ~ ɾ, Ø	mp ^h , nt ^h , ɲkx ^h mp, nt, ɲk	(stop devoicing; ɣ > Ø)
d.	Stage IV	ϕ, r, x β, l ~ ɾ, Ø	(m)p ^h , (n)t ^h , (ɲ)kx ^h (m)p, (n)t, (ɲ)k	(nasal deletion)
e.	Stage V	ϕ, r, x b, l-d, Ø	(m)p ^h , (n)t ^h , (ɲ)kx ^h (m)p, (n)t, (ɲ)k	(β > b, ɾ > d)

In (27a) I begin with Proto-Bantu in Stage I, where it is arbitrarily assumed that the proto consonants in question were (unaspirated) stops. In (27b), where Stage II represents early Sotho-Tswana, the six consonants are realized as continuants when not following a nasal. At this point the voiceless series is unquestionably aspirated in the postnasal environment. Postnasal devoicing takes place in Stage III in (27c), and [ɣ] is lost. In Stage IV in (27d), nasals are lost intramorphemically and on nouns whose roots are polysyllabic. Finally, in Stage V in (27e), [β] and [ɾ] become [b] and [d] in Standard Tswana.

This last change is important in that it reintroduces voiced stops in Standard Tswana. Today, Tswana /b/ is pronounced [b], although it used to be pronounced [β]. Tswana [d] is an allophone of /l/ found only before the high tense vowels /i/ and /u/. As indicated in (27b-d), it used to be pronounced [ɾ], as it is in certain Sotho-Tswana dialects.³⁶ These facts are crucial in understanding postnasal devoicing as a historical process. As stated by Krüger & Snyman (n.d.), "[b] still acts according to its historical fricative features represented as [β]. [d] is a positional (complementary) variant of /l/ before the high vowels /i/ and /u/. /ɣ/ is a voiced velar fricative which underwent historical elision before vowel commencing stems, but which appears again in plosivated form, /k/, when these stems are preceded by /N/" (p. 122). So, as a possible *synchronic* solution to postnasal

devoicing, why not “pretend” that Tswana [b] and [d] are still /β/ and /l/? In this case, we could derive postnasal devoicing by invoking the constraint *D, which, given the relative complexity of voiced stops, is non-controversially phonetically driven. With /β/ and /l/, we could then replace the tableaux in (24) with those in (28).

(28) Historical scenario involving the constraint ranking *D > *NT:

a. “normal”		b. Sotho-Tswana	
/m-βona/	*NT	*D	*NT
☞ m-bona		*	
m-pona	*!		

In the “normal” situation in (28a), *NT is ranked higher than *D, so the input /m-βona/ is realized [m-bona], as it is in most of Bantu. (A separate constraint will require that /β/ be realized as a stop by postnasal hardening.) In the Sotho-Tswana situation in (28b), on the other hand, *D is ranked higher than *NT, and devoicing occurs. However, in this interpretation, /mβ/ is realized [mp] (instead of [mb]) not because of the postnasal environment, but because high-ranked *D forbids voiced stops in all positions in this analysis (as it did historically).

Despite the fact that this analysis avoids the constraint *ND, the historical scenario no longer “works” in present-day Tswana. At least two problems arise. First, if *D is highly ranked, as in (28b), why is /β/ allowed to be pronounced [b], that is, bón-á ‘see’ (not *[βón-á]). Second, if *D is highly ranked, why are /li/ and /lu/ realized as [di] and [du]? Examples such as in (29a) clearly show that /l/ devoices to [t] after a nasal:

(29) More alternations involving l, d and t

a.	lw-a	‘fight’	→	n-twa	‘battle, war’
	lóm-á	‘bite’	→	n-tómá	‘bite me!’
b.	ópél-á	‘sing’	→	mo-ópéd-í	‘singer’
	bul-a	‘open’	→	bud-ile	(perfective)
c.	dúél-á	‘pay’	→	n-túél-á	‘pay me!’ (< /-lúél-/ ‘pay’)

In this analysis, one would say that [nd] is avoided in (29a) so as to satisfy the constraint *D. But why doesn’t *D force the /l/ of /li/ and /lu/ to devoice to [ti] and [tu] in (29b)? Similarly, why is /lu/ realized as [du] in forms such as (29c)?³⁷

We might argue one of two responses. First, we might pretend that [b] and [d] remain [β] and [ɾ] throughout the phonology, becoming [b] and [d] only in the phonetic implementation. Or, second, we might introduce a new family of constraints: I/O faithfulness to absolute onset-initial position. In this case we would say (i) that /β/ and /ɾ/ may not surface as such, but (ii) must maintain their [+voice] specifications in absolute onset-initial position. It is clear, however, that these ad hoc responses are merely “tricks” to avoid having to refer to the postnasal environment. On the other hand, once we admit the constraint *ND, everything falls into place. It is in fact hard not to accept *ND as motivating this important aspect of Tswana phonology.

D. Other Languages

To summarize the preceding subsections, we conclude, first, that most dialects within the Sotho-Tswana subgroup have an “unphonetic” process of postnasal devoicing. The process is non-neutralizing, since the proto voiceless stops spirantized to ϕ , r , x , as was seen in (26) and (27b). The historical scenario included hardening of the voiced continuants β , l , γ to b , d , g after nasals, then devoicing, as in (27c). As we have said, the historical devoicing of mb , nd , ηg to mp , nt , ηk could have been the result of general devoicing of voiced stops, because these occurred only after nasals. However, the historical explanation is not available as a synchronic solution, because Tswana now contains [b] and [d], which do not devoice, for example, /li, lu/ → [di, du], not *[ti, tu]. I therefore propose a constraint *ND that functions as a conspiracy, as was seen in (22) and (23).

While generally overlooked in studies on NC, Herbert (1986) mentions postnasal devoicing in Sotho-Tswana, which he sees as non-general. He seems to have Sotho-Tswana in mind when he states that “no language which exhibits distinctive voicing in consonants limits prenasalized consonants to only voiceless consonants, although all prenasalized consonants may be voiceless in a language without a voice contrast in the consonant system” (p. 249). We might therefore hypothesize that *ND > NT was “allowed” to occur in Tswana, because of two peculiarities of the system. First, there was no D other than in postnasal position, that is, there was no distinctive voicing on stops at the point in which the change took place. Voiced stops are very often spirantized in Bantu languages. Thus, many have surface oppositions between [p, t, k] vs. [β, l, γ], with the latter being realized

[b, d, g] after a homorganic nasal. If the lack of a (non-postnasal) contrast between voiced and voiceless stops is a sufficient condition for postnasal devoicing, we should then find *ND > NT in many other Bantu languages. Since *ND > NT is rare, perhaps it depends not on the absence of [b, d, g], but on another property of early Sotho-Tswana: Prior to the introduction of postnasal devoicing, *T had already spirantized, and *NT had become NT^h, such that the change *ND > NT (> T) did not create any mergers. In other words, at the stage just prior to postnasal devoicing, the actual contrast was between NT^h and ND. Thus, the voicing of D had become redundant, with VOT constituting the major perceptual cue. Under this latter interpretation, the voicing of D could have become undone by a process that Ohala (1993) terms “hypercorrection”: listeners could have “misparsed” the voicing of the D of ND, attributing it not to the D, but instead to the preceding N.³⁸

Whether other factors contribute to the ND > NT process can only be determined by studying the effects of this change in other languages where it occurs. Postnasal devoicing also applies in Makua, which, however, may have shared this innovation with Sotho-Tswana (Janson, 1991/1992). In order to find other cases of postnasal devoicing, it is necessary to travel thousands of miles away to the Northwest of the Bantu zone. Janssens (1993) has shown that *ND is realized T in Bubi, spoken off the coast of Cameroon on the island of Fernando Po. Among the Proto-Bantu/Bubi correspondences noted by Janssens (1992) are the following:

(30)	Proto-Bantu		Bubi
a.	*-cɛmbà	‘wildcat’	-cipà
b.	*-gènd-	‘walk’	-ét-à
c.	*-gàngá	‘root’	-àkà

Note the striking resemblance of Bubi -ét-à ‘walk’ in (30b) with Tswana -et-a ‘travel’ in (20b), both from *-gènd-. What is important about the ND > T process in Bubi is that the output frequently merges with *T, as seen in the following correspondences also provided by Janssens:³⁹

(31)	Proto-Bantu		Bubi
a.	*-pàpá	‘wing’	-pàpá
b.	*-jútó-	‘body’	-ótó

It thus appears that the result of the *ND > T process can be merger.

Mergers also occur in Punu, a northwest Bantu language spoken in Gabon. As seen in (32a), the first person singular prefix N- conditions the stopping and devoicing of voiced continuants (Fontaney, 1980):

(32) Postnasal devoicing (+ hardening) in Punu [northwest Bantu]
(Fontaney, 1980, pp. 73–74)

a.	m+β	→	mp	-βég-	‘give’	→	m-pégi dibága	‘give me the knife’
	n+r	→	nt	-rónd-	‘love’	→	é n-tondi	‘he loves me’
	ŋ+y	→	ŋk (-ŋg)	-yirig-	‘light’	→	n-kírigili múji	‘light the fire for me’
b.	m+p	→	mp	-pas-	‘split’	→	m-pásiri mwí:ri	‘split wood for me’
	n+t	→	nt	-tábul-	‘cut’	→	n-tábulili pé:mbi	‘cut bread for me’
	ŋ+k	→	ŋk	-kap-	‘tie’	→	átsí ŋ-kápa	‘he tied me up’

Here we see that the voiced continuants [β, r, y] not only become non-continuants postnasally, but also devoice (variably, in the case of the velar). (The nasal prefix also optionally deletes before a voiceless stop.) In (32b) we observe that there is a merger with /p, t, k/, so we are at a loss to explain, phonetically, why this devoicing takes place.⁴⁰ From a synchronic perspective, it would seem that postnasal hardening is accompanied by devoicing — even though the inputs /m+b/ and /n+d/ are not.

Up until now, all of the examples have come from Bantu. There is, however, reason to believe that *ND exerts an effect outside Bantu as well. Court (1970), for instance, reports on developments such as in (33) in certain Indonesian languages:

(33) Evidence for *ND in Indonesian languages (Court, 1970)

	Stage I		Stage II		Stage III
a.	NV	>	N [̃] V	>	N [̃] V
b.	NDV	>	N ^D V	>	NV

The languages in question begin with a contrast between /NV/ and /NDV/ in what I have identified as Stage I. In Stage II, the vowel of /NV/ in (33a) is subject to progressive nasalization (which continues until checked by an antagonistic consonant — or the end of the word). At or subsequent to Stage II, the oral release of /ND/ becomes weakened in (33b), shown by the subscripted D. As shown in Stage III, the oral release may subsequently be lost. The original opposition between /N/ vs. /ND/ thereby becomes transphonologized as a contrast between [+nasal] and [-nasal] on the following vowel. Examples from Court (1970) are presented in (34).

(34) Examples showing NDV > N^DV > NV (Court, 1970)

a.	Sundanese	[māni]	‘very’	[mān ^d i]	(mandi)	‘to bathe’
b.	Ulu Muar Malay	{mŋ ^(g) oet}	to twitch	[mŋōē?]		‘to bellow’
c.	Sea Dayak	[nāŋ ^(g) a] (nangga)	to set up ladder	[nāŋā]	(nanga)	‘to straighten’
d.	Měntu Land Dayak	{əm ^(b) ak}	‘gong stick’	{əmāk}		‘sleeping mat’
		{pīn ^(d) a?}	‘to love’	{pīnā?}		‘snake (sp.)’

The significance of these data for our study is that /NT/ is not altered in these languages. The endpoint of the changes in (33) is thus one not unlike Sotho-Tswana: NT is found, but ND is not — ruled out, presumably, by *ND, which, again, must be higher ranked than *NT. Instead of satisfying *ND by postnasal devoicing, these languages invoke postnasal D-deletion.

Given the teleological orientation of phonetic OT, it is interesting to ask why ND should become N in the first place. The apparent gain appears to be the avoidance of ND (the most natural NC!) — and at quite an expense: an earlier N/ND opposition is transphonologized as one of [±nasal] on the following vowel. By so doing, these languages create an unusual situation, where nasalization on vowels is contrastive only if a nasal consonant precedes. In Hyman (1975b), I speculated that because of progressive nasalization, the [±nasal] opposition on vowels becomes more salient to speakers than the N/ND opposition.⁴¹

That such a transphonologization is not required for the change ND > N to occur is seen from the Scots facts in (35).

(35) Nasal cluster simplification in Scots (Harris, 1994, pp. 85–86)

a.	[mp] : pump, lamp, limp	b.	[m] : thimble, tremble, number, limb, dumber
	[nt] : rant, sent, flint		[n] : handle, bundle, thunder, hand, send
	[ŋk] : sink, sank, donkey, wrinkle		[ŋ] : bangle, single, finger, hunger, linger, anger, sing, strong,

In (35a) we see that NT is not modified in Scots, while ND is clearly avoided in (35b).

Finally, note in (36) the similar avoidance of ND by gemination in southern Italian dialects, compared to standard Italian (in parentheses):⁴²

(36) Southern Italian dialects, where mb > mm, nd > nn (Rohlf, 1949)

	Within morphemes			Across morphemes		
a. Roman	piommo palomma monno quanno	(piombo) (palomba) (mondo) (quando)	'lead' 'wooddove' 'world' 'when'	'm mettò un nitu	(un bottone) (un dito)	'a button' 'a finger'
b. Neap.	tammurro sammuco gónnola vénnere	(tamburo) (sambuco) (gondola) (vendere)	'drum' 'elderberry' 'gondola' 'to sell'	nom mòglio nom mène	(non voglio) (non viene)	'I don't want' 'he doesn't come'
c. Sicilian	sammucu chiummu munnu quannu	(sambuco) (piombo) (mondo) (quando)	'elderberry' 'lead' 'world' 'when'	um masu nom manu un niri un nõrmu	(un bacio) (non vanno) (non dire) (non dormo)	'a kiss' 'they don't come' 'to not say' 'I don't sleep'

Certain of the relevant Italian dialects provide evidence that *ND is higher ranked than *NT. While all of Italian originally contrasted NT and ND, (37) shows how each of these have been affected across dialects:

(37) Typology of NT/ND in Italian dialects

a.	Type I :	NT > NT	ND > ND	e.g., Tuscan, Northern Italian [i.e. no change]
b.	Type II :	NT > NT	ND > NN	e.g., Romanesco, Salentino
c.	Type III :	NT > ND	ND > NN	e.g., Neapolitan, Sicilian
d.	Type IV :	NT > ND	ND > ND	[unattested]

What is crucial are the type II dialects, where ND is modified to NN without NT being affected. Thus, in Romanesco, *cantare* 'to sing' is realized *cantà*. Type III is the most widespread pattern in the affected area. As Michele Loporcaro puts it, "What you find in southern Italy is type III, with two side-belts, as it were, north and south of type II: in other words, the area of NT > ND is included in that of ND" (personal communication, 1999). Thus, as seen in (37d), there is no type IV dialect where NT > ND occurs without the gemination of *ND. This provides strong evidence that ND > NN is the prior process and that *ND is ranked higher than *NT in southern Italy.

E. Other Processes

In the preceding subsections we have seen that, although many languages have postnasal voicing, thereby motivating the constraint *NT, the reverse process of postnasal devoicing is also attested. In part to account for this, the constraint *ND was proposed. Synchronic phonology must therefore recognize both *NT and *ND, constraints which, ranked differently, account for the contradictory processes of postnasal voicing and devoicing. These results are in fact not isolated, nor limited to this pair of constraints. A close look at the different developments of NC throughout the Bantu language family shows a number of such contradictory synchronic processes, summarized in (38).

(38) Postnasal processes/"counter-processes" in Bantu

Process	Schema	Language	Counter-process	Schema	Language
Postnasal voicing	NT > ND	Yao, Kikuyu, Nande, Bukusu	Postnasal devoicing	ND > NT	Sotho-Tswana, Makua, Bubi
Postnasal affrication	NS > NTS NZ > NDZ	Kongo, Yaka, Tuki, Venda	Postnasal de-affrication	NTS > NS NDZ > NZ	Shona, Rwanda, Kinga
Postnasal aspiration	NT > NT ^h	Cewa, Swahili, Pokomo	Postnasal deaspiration	NT ^h > NT	Zulu, Ndebele, Xhosa, Swati
Postnasal nasalization	ND > NN	Ganda, Matumbi	Postnasal de-nasalization	NN > ND	Kongo, Yaka, Punu

Another common postnasal process is the affrication of fricatives. Examples are seen from (ki-)Kongo in (39), where again the first person singular prefix N-conditions the changes:

(39) Postnasal affrication in Kongo (Carter, 1984)

- | | | | | |
|----|--------------|---|-------------|-----------------|
| a. | /ku-N-fil-a/ | → | kú-m-pfil-a | 'to lead me' |
| | /ku-N-sib-a/ | → | kú-n-tsib-a | 'to curse me' |
| b. | /ku-N-vun-á/ | → | kú-m-bvun-á | 'to deceive me' |
| | /ku-N-zól-a/ | → | kú-n-dzól-a | 'to love me' |

On the other hand, many Bantu languages exhibit postnasal de-affrication. In the Shona examples in (40a), for instance,

(40) Postnasal-deaffrication in Shona (Hannan, 1959/1987)

- | | | | | | |
|----|----------|----------------|---|---------|-------------------------|
| a. | bvum-a | 'agree, admit' | → | m-vum-o | 'permission, agreement' |
| b. | mu-dzúwe | 'swing' | ~ | n-zúwe | 'swing' |

the initial /bv/ of the verb root *-bvum-* becomes [v] when nominalized with the homorganic class 9 prefix N-. The examples in (40b) show the dialectal realization of the same root /-dzúwe/ 'swing' in two different noun classes: class 9 vs. class 3. As seen, /dz/ is realized as [z] after the class 9 prefix N-.⁴³

Another example concerns aspiration. It is frequently pointed out that voiceless stops tend to aspirate after homorganic nasal prefixes. Examples are again cited from Kongo in (41).

(41) Postnasal aspiration in Kongo (Carter, 1984)

- | | | | | |
|----|---------------|---|----------------------------|-----------------|
| a. | /ku-N-pun-á/ | → | kú-m-phun-á | 'to deceive me' |
| b. | /ku-N-tál-a/ | → | kú-n-t ^h al-a | 'to look at me' |
| c. | /ku-N-kiyíla/ | → | kú-N-k ^h iyíl-a | 'to visit me' |

However, the reverse process is found in the Nguni languages in southern Africa. Thus, as seen in the Ndebele examples in (42), aspirated stops are deaspirated (and usually ejectives) when preceded by a nasal prefix.⁴⁴

(42) Postnasal de-aspiration in Nguni (Pelling, 1971; Galen Sibanda, personal communication)

- | | | | | |
|----|---------------------------|--------------|-----|----------|
| a. | ulu-t ^h i | 'stick' | pl. | izin-ti |
| b. | u(lu)-p ^h ondo | 'horn' | pl. | im-pondo |
| | u(lu)-p ^h awu | 'sign, mark' | pl. | im-pawu |
| c. | u(lu)-k ^h uni | 'firewood' | pl. | iŋ-kuni |
| | u(lu)-k ^h alo | 'waist' | pl. | iŋ-kalo |

The forms on the left involve the class 11 prefix *ulu-*, which can be simplified to *u-* if the noun stem has at least two syllables. The plural forms to the right are in class 10, which is marked by *iziN-* if the root is monosyllabic, otherwise by *iN-*.

Finally, Bantu languages have been found that nasalize vs. de-nasalize consonants in the postnasal environment. In the first case, I cite examples of Meinhof's Rule in Ganda:

(43) Postnasal nasalization ("Meinhof's Rule") in Ganda (Katamba & Hyman, 1991)

- | | | | | | |
|----|-------------|---|--------------|--------------------|---------------|
| a. | N-bomba | → | m-momb-a | 'I escape' | (*mbomba) |
| | N-banda | → | m-mand-a | 'I open up a way' | (*mbanda) |
| | N-banja | → | m-manj-a | 'I demand payment' | (*mbanja) |
| | N-banga | → | m-mang-a | 'I begin' | (*mbanga) |
| b. | N-limba | → | n-nimb-a | 'I lie' | (*ndimba) |
| | N-londa | → | n-nond-a | 'I choose' | (*ndonda) |
| | N-langa | → | n-nang-a | 'I announce' | (*ndanga) |
| c. | N-jamba | → | ŋ-namb-a | 'I help' | (*njamba) |
| | N-jonda | → | ŋ-nond-a | 'I twine' | (*njonda) |
| | N-jonja | → | ŋ-nonj-a | 'I make smart' | (*njonja) |
| | N-junga | → | ŋ-nung-a | 'I join' | (*njunga) |
| d. | N-gamba | → | ŋ-namb-a | 'I say' | (*ngamba) |
| | N-genda | → | ŋ-nend-a | 'I go' | (*ngenda) |
| | N-gengewala | → | ŋ-nengewal-a | 'I become a leper' | (*ngengewala) |

The examples in (43) show the nasalization of a voiced non-continuant when preceded by a nasal prefix and followed by a ND in the next syllable. On the other hand, postnasal denasalization is attested in Kongo dialects, Yaka, Punu and a few other languages in the general vicinity. The examples in (44) are cited from Yaka:

(44) Postnasal denasalization in Yaka (Kidima, 1991; Hyman, 1995)

- | | | | | | | | | |
|----|-----|---|-----|------|----------------|---|------------|-----------------|
| a. | N+b | → | mb | e.g. | [N-[bak-idi]] | → | m-bak-idí | 'I caught' |
| | N+d | → | nd | e.g. | [N-[duuk-idi]] | → | n-duuk-idí | 'I became wise' |
| b. | N+m | → | mb | e.g. | [N-[mak-idi]] | → | m-bak-iní | 'I carved' |
| | N+n | → | nd | e.g. | [N-[nuuk-idi]] | → | n-duuk-iní | 'I smelt' |
| | N+ŋ | → | ndy | e.g. | [N-[nem-idi]] | → | n-dyem-ené | 'I pushed' |

As seen, the N+D inputs in (41a) surface as unchanged. On the other hand, the N+N inputs in (44b) are realized ND. Although the initials merge in these examples, note that the perfective suffix, realized *-idi* in (41a), is modified to *-ini* when the root begins with an underlying N.

While it is not clear what is motivating the denasalization process in (44b), it is hard to see how this process, completely general in the language, can be seen as the result of a phonetically driven process (cf. §IV).⁴⁵

IV. CONCLUSIONS

On the basis of the preceding discussion, I conclude the following:

- (i) “Phoneticizing” phonology by incorporating *NT does not constrain phonology as implied in phonetically driven phonology.
- (ii) ND → NT exists as a process in Sotho-Tswana, which allows surface NT, but not *ND.
- (iii) The historical change, ND > N (with the transphonologization of the N/ND opposition as one of [±nasal] on following vowel), also creates a distribution where NT is allowed, but ND is not (Měntu Land Dayak, etc.).
- (iv) Other NC phenomena involve analogous contradictory processes (affrication vs. de-affrication, aspiration vs. de-aspiration, nasalization vs. de-nasalization).

On the one hand, these specific conclusions might be interpreted to support the general proposition developed in section II that phonetic determinism is not a property of synchronic phonologies, and therefore should not be incorporated as the driving force within synchronic phonological theory. On the other hand, the existence of what I’m calling “processes” vs. “counter-processes” may simply highlight the richness and complexity of the phonetic-phonology interface. Either way, we are left with the problem of explaining such bidirectionalities as those in section III.E. There are at least two possible explanations for the existence of the contradictory processes in (38).

First, the indicated processes are indeed phonetically driven, while the corresponding counter-processes are the result of non-phonetic factors, for example, restructuring, analogy, grammatical factors.

Second, both the processes and counter-processes are phonetically driven, but by different, sometimes contradictory demands.

It is this latter possibility that I would like to consider in this brief conclusion. As indicated in (45a), postnasal devoicing, affrication, aspiration, and denasalization fall within the class of processes frequently referred to as fortition, vs. the lenition processes of voicing, deaffrication, deaspiration, and nasalization in (45b).

(45)

- a. fortition: devoicing, affrication, aspiration and denasalization
- b. voicing: deaffrication, deaspiration, nasalization

It is tempting to attribute these contradictory processes to what Dressler (1985, pp. 41–42) refers to as the “age-old distinction between clarity (optimization of perception) and ease of articulation.” Could the process/counter-process distinction be due to this dichotomy? Specifically, can the processes in (45b) have an articulatory motivation — on the assumption that they would require less effort — while those in (45a) serve the function of reinforcing perceptual cues needed to make relevant contrasts in the respective languages?

Several colleagues have proposed to me that, although favored as an NC articulation, ND is perceptually non-optimal in terms of its opposition with N. Thus, when ND → NT in Tswana, the result is an output articulation that is more perceptually distinct from N than the input ND. The perceptual precariousness of an N/ND opposition would, in this interpretation, be resolved in favor of N/NT in Tswana, but would result in merger in situations such as in Sea Dayak, repeated in (46).

(46)

- a. NV > Nṽ
- b. NDV > NV

However, as I have already commented, it is hard to see what is “advantageous” or “optimized” in (46), where an opposition is created between oral and nasalized vowels only after nasal consonants. It would appear that one precarious perceptual contrast (N/ND) is replaced by an even worse one — nasalized vs. oral vowels contrasting only after nasal consonants. Presumably, (46b) is not articulatorily driven or these languages would have “fixed up” the nasal+voiceless stop sequence first. Thus, if certain of the NC counter-processes are perceptually rather than articulatorily driven, the force behind them may not be optimization.⁴⁶ An alternative diachronic interpretation, based on Ohala (1993), is indicated in (47).

(47) Alternative diachronic interpretation, based on Ohala (1993)

- a. NS > NTS hypocorrection [–cont, –nasal] transition between N & S is misinterpreted as intentional/structural
- b. NTS > NS hypercorrection [–cont, –nasal] spec. of TS is misinterpreted (factored away) as transition between N & S

In the case of postnasal affrication in (47a), the [–cont, –nasal] transition between a nasal and a voiceless fricative is misinterpreted as intentional and therefore phonologized as a structural property of the language. The counter-process in (47b), deaffrication, occurs when the [–cont, –nasal] specification of the voiceless fricative is misinterpreted as an intrinsic transition between the nasal a fricative (and hence factored away). Ohala’s notions of hypocorrection and hyper-

correction thus allow for the bidirectional postnasal processes in (38), but need to be further validated in the other cases.

Whether phonological states and processes reflect a tug of war between articulation and perception or between phonetics and grammar, or both, I hope to have shown that one does not predict what is attested vs. not attested on the basis of a single dimension alone. For reasons we have considered, synchronic input/output relations that mimic phonetically motivated sound changes will be more frequent than those that do not. Input/output relations will be less frequent if they require the interplay of more than one sound change and/or a restructuring which draws on the grammatical side of phonology, for example, the paradigm. Characterizing a phonological state as rare is, potentially, quite different from claiming that it is unattested. A phonological property may be unattested for one of two reasons.⁴⁷ First, we may not yet have found a language in which the right set of factors have interacted to produce such a state. In this case the property is, in principle, attestable. On the other hand, a phonological property may be unattested because it is ruled out by some universal principle of language. In this case, we might instead refer to it as unattestable. As pointed out in section II, a major goal of phonological theory has been to characterize what is a possible phonological system, that is, what is attestable vs. unattestable. Scholars will disagree with respect to how successful this program has been. As indicated, phonetic determinism is essential in understanding what is likely to become phonology. It appears to have less to say about developments subsequent to the phonologization process, since languages do develop “crazy rules” (Bach & Harms, 1968).

The major outstanding question, therefore, is the following. If the phonetics does not constrain post-phonologized phonology, what does? What determines the limits on “denaturalized” phonology? The general response has been to seek cognitive constraints on phonological computability. However, even admitting such limitations, we are still left with a vast array of possible phonologies. This is the negative result. The positive result of this study is that it is possible to gain insight into the workings of phonology by viewing it as the mediator of two poles — the phonetics and the grammar — and by taking an essentially diachronic perspective.

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NOTES

1. Anderson (1981, 1985) traces this view back to Baudouin de Courtenay (1895/1972). Many generative phonologists in the late 1960s and early 1970s were particularly impressed by the study of natural rules, culminating in the movements known as “natural phonology” (Stampe, 1969; Donegan & Stampe, 1979) and “natural generative phonology” (Vennemann, 1974; Hooper, 1976).
2. A number of intermediate positions can doubtless be distinguished between phonetic integration, on the one hand, and phonological autonomy on the other.
3. Pater’s constraint is given as *NC, where he uses C to stand for voiceless obstruents. In this study I use T to stand for voiceless stops, D for voiced stops, and C to stand for any obstruent.
4. This point has, of course, been repeatedly made in the literature (see especially Anderson, 1981). In my own work (Hyman, 1975a,b), I have emphasized the potential differences between synchronic and diachronic naturalness. The distinction is particularly useful in the case of tone (Hyman & Schuh, 1984). Many eastern and southern Bantu languages have a synchronic process by which a high tone is shifted to a metrically strong position, for example, the penultimate syllable, which can be several tone-bearing units to the right. Goldsmith (1987) has attributed this to a synchronic principle, the Tone–Accent Attraction Principle, whose effect would be to accomplish this shift. However, it is clear that such a long-distance shift could not have taken place in a single step, diachronically. Rather than a rule of high tone shift, other languages from throughout the Bantu zone have a rule of high tone SPREADING to a metrically strong position, which creates a sequence of high tone-bearing units. Some of these languages variably lower all but the last of these highs. The high-tone shift languages are, thus, those where this subsequent lowering process has become obligatory. Wherever evidence is available (see especially Cassimjee & Kisseberth, 1992, and Downing, 1990), it invariably points to the synchronically natural rule of high-tone shift deriving from the “telescoping” of the natural diachronic processes of high tone spreading and high tone lowering.
5. The opposite conclusion would be equally valid by the economy argument. In order not to duplicate, one should keep phonetics out of phonology: “Duplication of the principles of acoustics and acquisition inside the grammar constitutes a violation of Occam’s razor and thus must be avoided” (Hale & Reiss, 1998, p. 7).
6. Interestingly, the most common demonstration of complementary distribution in introductory linguistics courses may have this character: the (non-)aspiration of voiceless stops in English.

7. Thus, compare Vennemann's statement offered as a prelude to his arguments in favor of incorporating the syllable into then-current phonological theory: "I require of a theory of grammar that it provide a notational framework in which grammatical processes are formulizable in a general and explanatory way. It is not sufficient to require generality of a grammatical formulation. An intelligent linguist can express any grammatical process in any framework without loss of generality. The more important requirement is that of explanatoriness. A language-specific grammatical formula (i.e., a rule in a grammar) must directly refer to its own motivation, i.e., its explanation in the metatheory, the theory of grammar" (Vennemann, 1971, p. 1).
8. The intersection of phonetics and grammar in (1) can, in turn, be interpreted on different planes, for example, synchronic, diachronic, and sociolinguistic, and must also intersect with semantics and pragmatics.
9. Note that Ohala makes another prediction. If the C_1 of a VC_1C_2V sequence is released, then we do not expect place assimilation at all. In fact, cases of "antigeminatio" (McCarthy, 1986) bear this out. In Afar (Bliese, 1981), a syncope rule derives *digb-é* 'I married' from /*digib-é*/. The same rule fails to apply to /*adad-é*/ 'I/he trembled,' thus realized [adad-é], because the ungrammatical output **add-é* would result in two identical consonants in sequence (an OCP violation, as McCarthy points out). Bliese (1981, p. 25) expresses his surprise at this condition: "Since the language accepts geminates, it is not obvious why they are avoided here." The answer comes from the fact that coda consonants are released in Afar: "Nonhomorganic consonants have an audible transition when contiguous. The sound of the release precedes that of the onset of the following consonant. Between fricatives and voiced consonants, and after voiced consonants, the release is a shwa. [. . .] After other voiceless consonants, the release can be heard by the escaping of the oral air trapped behind the closure before the beginning of the next closure" (Bliese 1981, p. 246), that is, the above-cited form *digb-é* is pronounced [dig^hbél. Thus, what would be expected if syncope applied to /*adad-é*/ is [ad^hd-é]. I conclude that what is thus avoided in Afar is a sequence of homorganic *released* consonants (cf. Odden, 1988 for additional discussion of anti-gemination in terms of release).
10. There are other examples as well. One that is particularly striking comes from Hayu, a Himalayish language spoken in Nepal (Michailovsky, 1988). In this language a suffix-initial velar consonant will assimilate in place to a preceding labial-final root consonant, for example, /*dip-ŋo*/ 'he pinned me (in wrestling)' → *dipmo* (→ *di^hmo* by other rules). Also presumably related to the base/affix distinction are the suffixing languages in which C-initial suffixes drop their C when the base to which they are attached ends in a consonant.
11. The reason for placing the [w] in parenthesis is that it remains present only when a labial immediately precedes passive -w-. In other cases it is lost, for example, Proto-Bantu **i-N-búa* > *i-n-ja* 'dog.'
12. Sibanda (1998) speculates that this has to do with the fact that Ndebele [β] corresponds to implosive [ɓ] in other Nguni languages, for example, Xhosa. The palatalized consonant thus appears to preserve the historical glottality.

13. Interestingly, non-suffixed -VC- roots take the passive allomorph -iw-, which does not condition palatalization. Thus, -eβ-a 'steal' passivizes as -eβ-iw-a 'be stolen', not *-ec'w-a (Sibanda, 1998).
14. The best known inhibitory factors appear not to be segmental, but rather prosodic, for example, rules that are sensitive to syllabification. Thus, the restricted environment VC__CV in which syncope applies in Yawelmani (Kisseberth, 1970) is designed to guarantee that there will be no complex onsets or codas in a Yawelmani syllable. Another example is the anti-gemination phenomenon cited in note 9, which also is a response to impending syncope. Much rarer are similar inhibitory effects to strictly segmental rules. Cf. in this connection the discussion in section III.A concerning the non-devoicing of prenasalized consonants in Basaá.
15. Where *p does not fricate to [s], it instead weakens to [w], for example, *-pá- → -wá- 'give', except before *j and lax *i, where *p > y, for example, *-pít- > -yít- 'pass'. This has nothing to do with the frication process under discussion here.
16. In Hyman (1997), I argued for the opposite interpretation: frication began tautomorphemically and later spread to heteromorphemic contexts, not quite reaching the labials. In this interpretation, one must, however, ask why only *p and *b are exempt from frication in derived environments.
17. Cf. "it is only through a fine-grained phonetic analysis that a true and general account of phonological processes may be gained" (Ohala, 1997).
18. Also ultimately to be considered are sequences such as N+TS, N+DZ, N+L, N+G, and N+N, where L = liquids and G = glides.
19. Although the likely underlying form of this prefix is alveolar, that is, n-, I show it here as N-. Note also that the consonants written c, j are affricates, that is [tʃ, dʒ].
20. Interestingly, Bantu languages that voice stops after nasals split in their treatment of N + voiceless fricatives. Yao and Bukusu have nasal effacement (NS → S), while Kikuyu and Nande have voicing (NS → NZ).
21. What one would ideally like to find is a language where an NV- prefix loses its vowel before a consonant-initial root unless that consonant is a voiceless stop, for example, mu-bVVCV → m-bVVCV, but mu-pVVCV does not become *m-pVVCV. While I have not found any such case, see the discussion in section III.B of an analogous rule in Tswana that has direct relevance to this issue.
22. The voiced variants may also be pronounced as the continuants [β, r, ɣ], particularly intervocally.
23. Since I do not have instrumental data, I cannot state with certainty that there is a complete lack of phonetic devoicing of ND phrase-finally. However, these consonants have always been transcribed and described as voiced, including by native speakers: "la présence d'une nasale non syllabique précédente sonorise la consonne et exige que l'on marque la variante sonore. On aura ainsi [ámβ] et non [ám̥p]. [. . .] les lois du langage exigent que le phonème soit sonorisé" (Lemb & de Gastines, 1973, p. 25). This conforms with my own observations, having worked on Basaá myself with several speakers.

24. Unaspirated stops are variably ejectives in Tswana, which most scholars consider to be a redundant feature of unaspirated stops, perhaps “enhancing” their contrast with aspirated stops.
25. This is reminiscent of what happens when NT undergoes aspiration. Whereas some languages, for example, ki-Kongo and ci-Cewa, have NT → NT^h, others such as Swahili and Venda lose the conditioning nasal and have NT → T^h.
26. The view that devoicing has become morphologized has been expressed by certain Sotho-Tswana specialists. Dickens (1977, pp. 166–167), for instance, takes this position because the reflexive prefix *i-* also has this devoicing effect: *i-pon-e* ‘see yourself!’, *i-tis-e* ‘watch yourself!’, *i-karab-e* ‘answer yourself!’ Dickens supposes that an earlier form of the reflexive prefix was **in-*, with the nasal dropping out in all environments.
27. This is not to say that there is no difference between “phonological rules of different types” (Anderson, 1975). Within lexical phonology and morphology (Kiparsky, 1982, 1985), it is known that so-called stratum 1 rules may have different properties from either stratum 2 or post-lexical rules. Perhaps it is, then, stratum 1 rules that need not be phonetically driven. Since stratum 1 typically refers to the stem domain in Bantu, while the first person singular prefix *N-* comes in at stratum 2, we would have to treat these alternations as stem alternates if we were to seriously pursue this proposal.
28. The table in (21) includes only N + [–cont] consonants. Creissels also include a few borrowings that have nasal + voiceless fricative, for example, *émfílɔ́pó* ‘envelope’, *khánsàtá* ‘concert’, *pénsélé* ‘pencil’ (cf. also the last syllable of *ámbulénsi* ‘ambulance’). These forms are exceptional in that we expect postnasal affrication, that is, NS → NTS^h, in Tswana. Thus, non-exceptional N+ɸ and N+s becomes [mp^h] and [nts^h], respectively (cf. (26)).
29. It also apparently doesn’t apply when the root begins with /m/. However, it optionally applies, with dialectal variation as well, when the root-initial consonant is /ɸ/ (from Proto-Bantu *p). When it does apply in this context, /ɸ/ obligatorily becomes [h], for example, *mu-ɸáxó* ~ *m-háxó* ‘food for a journey’ (Cole, 1955/1992, p. 48).
30. Thus, **mu-tánd-é* ‘love him!’ is realized *mú-rát-é* in Tswana vs. *mú-rád-é* in Lobedu.
31. Of course, the interesting question is why /b/ and /l/ do not undergo devoicing here, as they do after the first person sg. object prefix *N-*. I will demonstrate below that postnasal devoicing is a consequence of postnasal hardening, which applied only to input N+C.
32. Generally speaking, *k is realized [k^h, h] before *u and [kx^h, x] before other vowels.
33. Recall, however, from note 26, that the proto consonants have the same realization after reflexive **i-* (or **iN-*?) as they do after *N.
34. In Dickens (1977), the same author assumes that *ND was first simplified to D, which then became T’. In my survey of Bantu I have, curiously, not found any language where *ND > D. On the other hand, as seen in (30) below, some quite distant languages have undergone the same *ND → T change as in Sotho-Tswana. Dickens does indicate in his note 9 that *ND > NT’ > T’ might also be a possible interpretation (and, in any case, would have to be assumed where the N is not deleted).

35. As indicated above, it is also possible that aspiration already occurred on Proto-Bantu voiceless stops, in which case it was preserved postnasally, but fed affrication + deaffrication in other contexts (k^h > kx^h > x).
36. This change from [r̥] to [d] in Tswana and elsewhere in Sotho-Tswana is quite recent. Cole (1955/1992, p. 28) still records it as such, but indicates that [d] “is now used by most of the younger generation of Tswana speakers.” Other scholars with whom I have spoken indicate that they have never encountered [r̥].
37. The same questions arise in an analysis that would represent these two consonants as underspecified for [continuant].
38. Besides using hypercorrection as a “wild card,” Ohala actually would be suspicious of this interpretation for two reasons. First, he does not consider the feature [voice] to be a good candidate for dissimilation. Second, he does not expect dissimilatory processes to create new segments. The only source of unaspirated (variably ejective) voiceless stops is from *ND in Sotho-Tswana.
39. Bubi falls within those northwest Bantu languages that have “double reflexes” of the Proto-Bantu consonants (Janssens, 1993). Thus, *p also sometimes corresponds to [h], while *r sometimes corresponds to [l]. *k seems always to drop out, however.
40. Diachronically we can assume that there has been a rule inversion, that is, that [β, r, ɣ] were originally voiceless stops, preserved as such in postnasal position. For further discussion, see Blanchon (1991).
41. In Ohalian terms, listeners parse the NDV sequence not as the original, intended ND-V, but rather as N-DV, where the oral release of the nasal is attributed to the orality on the V (which in turn stands in contrast to the nasalized vowel of /NV/). As a consequence, they then hypocorrect and subsequently leave out the oral release D altogether. Cf. Ladefoged & Maddieson (1996, pp. 103–104) for further discussion of the phonetic issues involved.
42. Only the labial and dental changes are indicated in (36), although *ɲj* > *ɲɲ* is also often attested. On the other hand, Italian dialects show a reluctance to extend the process to create a geminate velar nasal (*ŋg* > *ŋŋ*). The reason for this appears to be one of structure-preservation, since [ŋ] otherwise occurs only before a velar stop in Italian. It is interesting that Romance languages avoid the velar nasal, while Germanic languages seem to welcome the new “phoneme” (e.g., all varieties of English have lost the final *g in words like *sing*, *strong*). The difference appears to have to do with the origins of the ND simplifications. Whereas the process first affects ND in coda position in Germanic (and then spreads to intervocalic position), ND > NN is an intervocalic process in Italian. Thus, what appears to be avoided in the latter case is pre-vocalic [ŋ]. As has often been noted, [ŋ] appears to be privileged in coda position and avoided in onset position. Many languages restrict [ŋ] to coda position, where diachronic *m, *n > ŋ also frequently occurs (see, e.g., Chen, 1973).
43. While postnasal affrication is a form of postnasal hardening, involving an intrusive or emergent stop (Clements, 1987; Ohala, 1997), postnasal de-affrication is, I assume, a false parse or hypercorrection (Ohala, 1993).

44. While researchers have tended to view the opposition as one of VOT, again, the issue of unaspirated vs. ejective comes up. Perhaps the process can be viewed as postnasal ejection, rather than postnasal deaspiration (which I have, thus far, not found to be attested without concomitant glottalization). It is possible that we have an areal feature here. The Nguni languages have been in contact with the Sotho-Tswana languages — and both have NT'. What is interesting is that the former develop NT' from deaspiration, while the latter develop NT' from devoicing.
45. Meinhof (1932) speculates that an analogy is involved, perhaps a false extension in undoing Meinhof's rule.
46. There is the additional problem of finding support for the claimed optimizations. One might, for example, claim that denasalization occurs so as to enhance the N/NN distinction, which now becomes N/ND. However, what about the resulting merger of /NN/ with /ND/? Does it matter? Do certain claimed perceptually driven processes depend on their being (or not being) a prior opposition? Some of these issues are taken up by Flemming (1995) and others, but more work is clearly needed in this area.
47. See Hyman (1975a), Anderson (1981), Janda (1984), Blevins & Garrett (1998), Dolbey & Hansson (1999), among others, for further discussion.

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