On the Peripatetic Behavior of Aspiration in Sanskrit Roots

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This paper deals with Grassmann's and Bartholomae's Laws in Sanskrit. The former has the effect of distributing aspiration inside a root. The second accounts for the progressive assimilation of voicing and aspiration. Grassmann's Law, for example, is responsible for the alternation between *bodh-ati* '3rd sg. pres. ind' of the root /bhaudh/[1] 'know, wake' and *bhot-sya-ti* '3rd sg. fut' you see in (1). In the former aspiration appears on the final consonant of the root while in the latter it appears on the initial consonant of the root. Grassmann's Law is intended to account for this migratory behavior. Bartholomae's Law, on the other hand, is intended to account for what happens in the form *buddha* 'past participle' from /bhudh + ta/ where in addition to progressive voicing assimilation, aspiration migrates from the root final consonant to the following consonant.

(1) **Root /*bhaudh*/ 'know, wake'**
   a. *bodh-ati* 3rd sg. pres ind ([au] → [o])
   b. *bodh-mi* 1st sg. pres ind
   Grassmann's Law
   c. *bhot-sya-ti*   3rd sg fut
   d. *a-bhut-si*   1st sg aorist
   e. *bhut*   root noun, nom sg
   f. *bhudbhis*   root noun, instr. pl.
   g. *bhuddhvam*   2nd pl pres imp
   Bartholomae's Law
   h. *buddha* past participle
   i. *bodhi*   imperative

   The focus of this paper is the migrating behavior of aspiration in Sanskrit diaspirate roots.

   Diaspirate roots have a voiced stop in the onset and the coda of the root. One of these two stops is aspirated. However, which one is aspirated depends of the segmental context. Specifically, before sonorant-initial suffixes, it is the root final stop to be aspirated; the root initial stop, instead, is not (e.g., *budh-*). Before obstruent-initial suffixes or in word-final position, the root final consonant is not aspirated in addition to be devoiced. In this case, it is the first stop that is aspirated, (e.g., *bhut-*). We will propose the following:

   1) Diaspirate roots are underlyingly characterized by multiply linked laryngeal features between onset and coda stops. We will demonstrate that independent diachronic evidence requires such a structure for these roots.

   2) There is a rule which spreads the laryngeal feature of a voiced aspirate consonant onto a following stop (Bartholomae's Law proper).

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[1] This root is usually listed in the traditional grammars of Sanskrit in the zero grade form /*budh*/. Here we give it in the full grade. Also, as discussed later, we assume that diaspirate roots such as this one are characterized by having a [+spread glottis] feature multiply linked both with the onset and to the coda stops (i.e., /*bhaudh*/).

3) There is a constraint that disallows the linking of the feature [+spread glottis] (aspiration) to multiple consonants. Delinking all of the links except the last one repairs violations of this constraint.

4) We also assume an analysis of Sanskrit syllabification that supposes that, as in English and many other languages, segments of a certain class are not permitted in coda position.

At the end of the paper, We will discuss the behavior of diaspirate roots in Indo-European languages other than Indo-Iranian and Greek, and propose a modification of the constraint accounting for Grassmann's Law.

1. Basic Facts

(2) illustrates the relevant alternations we will be concerned with (see Whitney (1889), Wackernagel (1896)).

(2)	___ /s/	___ /t/	__ ##	___ V	__ [+sonor	
raudh/rudh	rot-sya-ti (l	rud-dhá	á-raːut	á-rodh-at	á-rudh-ma rudh-yá-te	'obstruct'
yaudh/yud	yot-syá-ti	yud-dhá		yódh-at	yúdh-ya-ti	
rādh	raːt-syá-ti (	raːd-dhá		raːdh-ati	raːdh-ya	'succeed'
dah	dhak-ṣyá-t	dag-dhá	a-dhak	dáh-ati	dah-yá-te	'burn'
dagh		dhak-tám	dhak	-dagh-as (ɓ	dagh-yáːs dagh-ma	'reach to'
grath		gr̥-ṇa-t-ti			grath-ya-te grath-náː-tı	'tie'
prach/pr̥ch	prak-ṣya- (ch-s → ks		á-praːṭ (ch→ṭ/__#,	pr̥ch-áti	pr̥ch-yá-te	'ask'
vaid/vid	vet-sya-ti (	vit-tá		vi-n-daːti	vid-ya-te	'find'
bhaid/bhid	bhet-syáte	bhi-ná-t-ti	á-bhet	bhédati	-bhíd-ya	'split'

The following generalizations on the behavior of diaspirate roots can be proposed (based on Steriade (1987)):

(3) When the diaspirate root appears before a suffix beginning with_____

(i) a sonorant, the final root stop is aspirated. The initial one is not.
a-bodh-am, bodh-mi

(ii) /s/, it is the first voiced stop of the root to be aspirated (the so-called *throw-back* of aspiration). In this case, the final one is deaspirated and devoiced:
bhot-si, bhut-sva

(iii) voiceless stops (/T/, /Th/), the whole cluster becomes voiced, aspiration occurs after the last member of the cluster, (i.e., DDh); the initial stop is not aspirated:
bud-dhas (from dh-th) *bud-dha* (from dh-t)

(iv)   voiced aspirates, aspiration occurs after the last member of the cluster, (i.e., DDh); the initial stop is not aspirated:

bodhi from *bhaudh+dhi* 'awake'–imperative (see also *dug-dhi* (from gh-dh) imperative of root *dhaugh* 'milk' cf. *doghati/dhoksyate*)
[There are exceptions: in *bhud-dhvam* from *budh-dhvam* there is throw-back of aspiration and deaspiration of the final root stop.]

(v)   Finally, if the diaspirate root is in word-final position, there is devoicing and deaspiration of the final stop and *throw-back* of aspiration:

a-bhot from /*a-bodh-t*/

For the other root types, the generalizations in (4, 5) and (6) hold. The overriding generalization common to all of them is that there is deaspiration and desonorization in an obstruent in word final position and before another obstruent. None of these processes occurs before a sonorant and before a syllabic nucleus. This generalization can be straightforwardly set in terms of syllable structure: in Sanskrit, there is deaspiration and desonorization of an obstruent in coda position.

(4)   In roots that end with a voiced aspirate stops but in which the first consonant is not a voiced stop (e.g., /*raudh : rudh*/ 'obstruct', /*sa:dh : sadh*/ 'succeed', /*tr̥Gh*/ 'crush'), we find the following:

(i)   before a sonorant the aspirate is preserved:
rudh-mas, rodh-ati   sadh-noti, sa:dh-ati tr̥Gh-ati, tr̥Gh-ya-ti

(ii)   before /s/ loss of aspiration and devoicing occurs:
rot-sya-ti   sa:t-sya-ti   tark-sya-ti

(iii)   before /t/, /th/ the cluster becomes voiced and aspiration appears only after the last member of the cluster:
rud-dha sa:d-dha: tr̥-ḍha (Gḍh -> ḍh)

(iv)   word-finally: loss of aspiration and devoicing:
a-raut   sa:t   ma -tart

(5)   In roots that end with a voiceless aspirated stop: /*grath*/   'lie'

(i)   before a sonorant the aspirate is preserved: *rath-na:-ti, grath-ya-ti*

(ii)   no examples before /s/:   [*prach-sya-* → *prak-_ya-*]
                                                          ch-s → *kṣ*

(iii) before /t/ loss of aspiration: *gr̥-na-t-ti*   [*pr̥ch-ta* → *pr̥k-ta*]
                                                          ch-t → *kt*

(iv)   word-finally there are no examples: [*prach* → *pra:t*]
                                                          ch → *t*

(6)   In roots that end with a voiced unaspirated stop:

(i)   before sonorant voicing is preserved: *bhédati -bhíd-ya*
(ii)   before /s/ there is devoicing: *bhet-syáte (b)*
(iii) before /t/ there is devoicing: *bhi-ná-t-ti*
(iv)   word-finally there is devoicing: *á-bhet*

There are several problems that must be explained with regard to diaspirate roots.

1) In these roots, when there is the loss of aspiration and devoicing in coda position, there is also *throw-back* of aspiration. The obvious question, then, is why there should be such a relationship between this neutralization process and the *throw-back* of aspiration.

2) Why does *throw back* occur only in diaspirate roots where the initial consonant is a voiced stop, and not in other root types, as for example those beginning in a voiceless stop.

3) Given that neutralization affects all types of laryngeal features, one also needs to ask why these features are not thrown back in the neutralization process, in the same way as aspiration of the voiced aspirates in diaspirate roots.

4) There is the question of why the process of *throw-back* is restricted to root syllables.

We answer these questions by proposing that the diaspirate roots have the underlying structure in (7). (The representations in (7, 8, 9) are simplified. See below for discussion.)

(7)

(e.g. *bh(a)udh*)
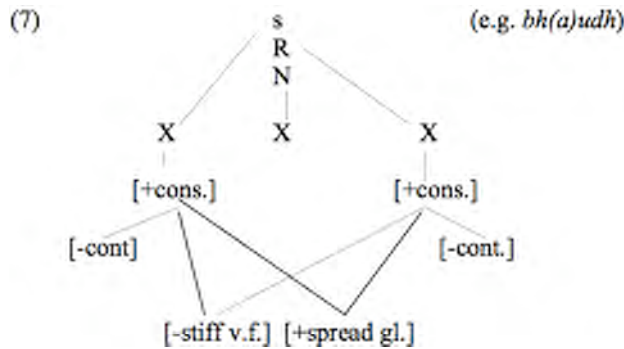
The migrating behavior of the aspiration features is due to two processes of delinking:

1) The first delinks the marked feature [+spread glottis] together with the other marked laryngeal feature [-stiff vocal folds], in coda position. They are replaced by the unmarked [+stiff vf.] and [-spread glottis]. This process results in the surface structure in (8b);

(8)   a.   b.

cf.   *bhudh.syate* (=8a)   →   *bhut.syate* (8b)
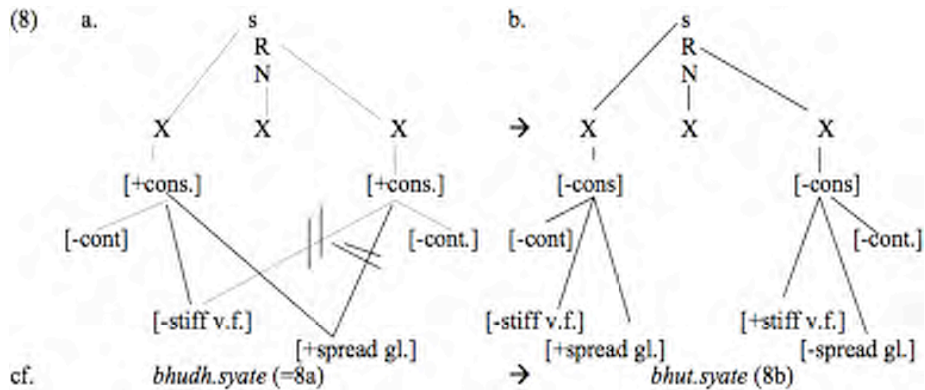
2) The second process delinks all feature specifications for [+spread glottis] except the final one in a linked cluster. This process results in the surface structure in (9b).

(9)
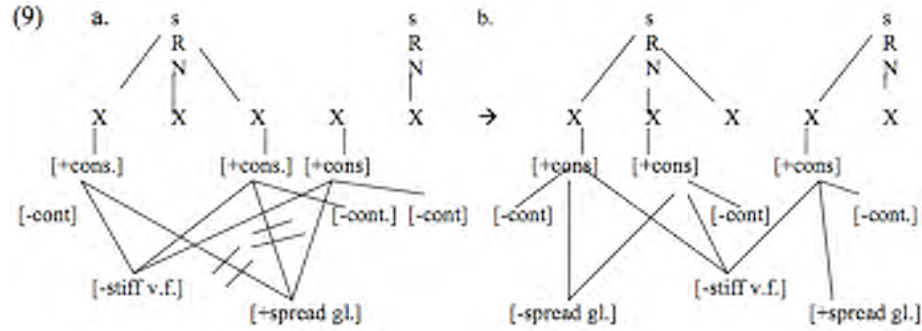
cf.   *bhudhdha* (=9a) (from *bhudh+ ta* after application of Bartholomae's Law → *buddha* (=9b)

Before turning to an analysis of the alternations characterizing Sanskrit diaspirate roots, we consider independent evidence for the representation in (7). This independent evidence is provided by the restrictions on root structure in IE.

2.   Restrictions on Laryngeal Features in PIE Roots

We begin our exposition with a review of the restrictions on the co-occurrence of laryngeal features in the same root in Indo-European. These restrictions are of fundamental importance in understanding the behavior of diaspirate roots. We will first consider Sanskrit and then turn to the proto-language.

The consonantal system of Sanskrit is given in (10):

(10)
p	t	ṭ	c	k
b	d	ḍ	j	g
ph	th	ṭh	ch	kh
bh	dh	ḍh	jh	gh
	s	ṣ	ś	h

The distribution of voicing and aspiration in this consonantal system is accounted for by constraints such as those in (11).

(11) Marking statements on the distribution of voicing and aspiration:
   a.   Obstruents:
       i.   *[-continuant, -stiff vocal folds] /[___, -sonorant]
            <stops are voiceless>
       ii. *[-continuant, +spread glottis] /[_____, -sonorant]
            <stops are unaspirated>
       iii. *[+spread glottis, -stiff vocal folds] /[___, -continuant,-sonorant]
            <aspirated stops are voiceless>
       iv. *[+continuant, -stiff vocal folds] /[___, -sonorant]
            <fricatives are voiceless>
       v.   *[+continuant, -spread glottis] /[_____, -sonorant]
            <fricatives are aspirated>

b.   Sonorants
    i.   *[+sonorant, +stiff vocal folds]
    ii. *[+sonorant, +spread glottis]
       < All sonorants are voiced, unaspirated >

In Sanskrit (11ai, ii, iii) are deactivated. All other marking statements are active. In comparison with the PIE system, Sanskrit allows voiceless aspirated stops, which—as discussed in Calabrese and Halle (1998)—were accidentally absent in the proto-language. Otherwise, Sanskrit has the same active marking statements as the Proto-language.

The co-occurrence of stops in the same Sanskrit root is severely restricted. Steriade (1987) outlined these restrictions in the chart in (12) (C_1, C_2 refer to the positions of the consonants in a canonical root (C_1 (R)V(R)C_2):

(12)

C_2: C_1:	-stiff v.f stop	+stiff v.f stop	-stiff v.f, +spr. gl. stop	son./spir.
-stiff v.f. stop	one? *(gad)*	lots *(dyaut)*	lots *(daugh)*[2]	lots *(gam/dvais)*
+stiff v.f. stop	lots *(pad)*	lots *(pat)*	few *(targh)*[3]	lots *(kar/pais)*
-stiff v.f. +spr. gl.	Few DhXD[4] *(bhaid)*	few, late *(ghat)*	none	lots *(bhar/ghas)*
son/spir.	lots *(mad)*	lots *(vak)*	lots *(vadh)*	lots *(mar/vas)*

There is no problem in the case of roots containing a sonorant or a fricative, as can be seen in the last row and the last column. There is also no problem in the case of roots containing voiceless stops or one voiced stop and one voiceless stop. However, there are almost no roots containing voiced stops with the exception of /gad/.

In surface representations there are no roots containg a voiced aspirate stop in onset and coda position. However, there are roots in which a voiced aspirate stop can appear in onset or coda position depending on the syllabic context: these are the so-called diaspirate roots, which will be discussed later. There are many diaspirate roots. A second group of roots containing a voiced aspirate include: i) roots where a voiced aspirate stop is the initial root consonant and a voiced unaspirated one is the final one. Roots of this type are rare. ii) roots with voiceless unaspirated and voiced aspirated stops in either initial or final position. Also roots of this type are rare.

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[2] This is the traditional representation of these roots. However, these are the so called diaspirate roots for which we are assuming the linked structure in (7). So according to us, these roots should actually be represented as voiced aspirate in onset and coda. (i.e., *dhaugh*). For the sake of the analysis we keep the traditional representation in this table.

[3] There is one exception: roots are possible where the voiceless stop appears as the C_1 consonant and is preceded by the fricative /s/ (e.g., (*staigh* 'stride, step'). See below for discussion.

[4] An exception, however, is provided by roots where the second voiced unaspirate stop is palatal (e.g., *bhaj* 'divide, share'): there are several roots of this type. The reasons for this exception are not clear to us.

Similar restrictions held in the proto-language, whose system of root structure we can reconstruct looking at root structure in the other Indo-European languages in addition to Sanskrit. However, there is a fundamental difference. The difference is that in the protolanguage, roots containing voiced aspirated stops were possible in surface representations. Otherwise, we have the same situation as in Sanskrit. We can thus reconstruct the situation in (13) for the proto-system (where the asterisk means the absence or rarity of a root):

(13) a. C_1 V C_2 b. C_1 V C_2 c. *C_1 V C_2
$[+\text{st.v.f.}]$ $[+\text{st.v.f.}]$ $[-\text{st.v.f.}]$ $[+\text{st.v.f.}]$ $\begin{bmatrix} -\text{st.v.f.} \\ +\text{spr.gl.} \end{bmatrix}$ $[+\text{st.v.f.}]$

d. C_1 V C_2 e. *C_1 V C_2 f. C_1 V C_2
$[+\text{st.v.f.}]$ $[-\text{st.v.f.}]$ $[-\text{st.v.f.}]$ $[-\text{st.v.f.}]$ $\begin{bmatrix} -\text{st.v.f.} \\ +\text{spr.gl.} \end{bmatrix}$ $[-\text{st.v.f.}]$

g. *C_1 V C_2 h. C_1 V C_2 i. C_1 V C_2
$[+\text{st.v.f.}]$ $\begin{bmatrix} -\text{st.v.f.} \\ +\text{spr.gl.} \end{bmatrix}$ $[-\text{st.v.f.}]$ $\begin{bmatrix} -\text{st.v.f.} \\ +\text{spr.gl.} \end{bmatrix}$ $\begin{bmatrix} -\text{st.v.f.} \\ +\text{spr.gl.} \end{bmatrix}$ $\begin{bmatrix} -\text{st.v.f.} \\ +\text{spr.gl.} \end{bmatrix}$

As we can see in (13), certain roots are not possible: 1) roots containing voiced stops (cf. (13e); 2) roots containing a voiceless stop and a voiced aspirated stop (cf. (13c and g)).

McCarthy (1988) proposes that the fact that root morphemes containing voiced consonants are not possible is due to an OCP-type constraint disallowing adjacent identical laryngeal nodes containing marked features. It is given in (14):

(14) [X   X $]_{\text{root}}$
     [+cons]   [+cons]

     Laryngeal   Laryngeal

     αF_1 αF_1 (where αF or bF is a marked feature specification)
          βF_2 βF_2

The marking statement in (11a) characterizes the feature [-stiff vocal folds] in stops as marked. The impossibility of the roots in (13e) is therefore accounted for.

The obvious question now is why root morphemes containing voiced aspirated consonants as C1 and C2, i.e., (13i), are possible despite the fact that the feature [+spread glottis] is obviously marked. McCarthy proposes that the solution to this problem lies in the impossibility of (13c) and (13g). Specifically, he argues that this type of root is impossible because of the process in (15) which affects voiceless stops in roots also containing voiced aspirated stops.

(15)   X   X
          [+cons.]   [+cons.]
[-cont]   [-cont]

     Laryngeal   Laryngeal

[+stiff v.f]   [-stiff v.f.] [+spread gl.]

The process in (15) creates roots such as that in (16) where the features [-stiff v.f] and [+spread gl.] are linked with the C_1 and C_2 consonants of the root:

(16)

Roots such as those in (13i) displaying a voiced aspirate in C_1 and C_2 have the structure in (16). Otherwise roots containing voiced aspirates as in (17) are disallowed by the constraint forbidding adjacent identical marked laryngeal nodes.

(17)   *
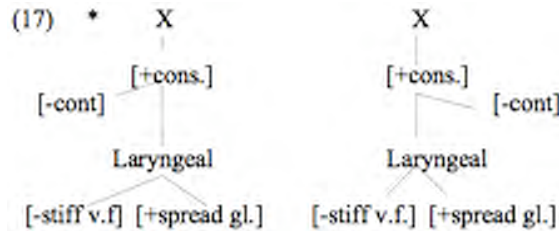
The roots with the linked structure in (16) are the diaspirate roots of Sanskrit.[5,6]

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[5] After the introduction of Grassmann's Law in the Indo-Aryan, the roots in (13f), as well as those in (13h), were reanalyzed as diaspirate roots (see Sag (1976), Schindler (1976)).

[6] An exception to the generalization that there are no voiceless stops in root position if there is a voiced aspirated stop in root coda position occurs when the root onset stop is preceded by /s/: there are many roots like /steigh/ 'stride, step'. Given the analysis just proposed, this means that rule (15) does not apply if the onset stop is preceded by /s/. If this is correct, roots such as [†]/sdheigh/ do not exist. Thus, (15) does not apply in a structure like (i):
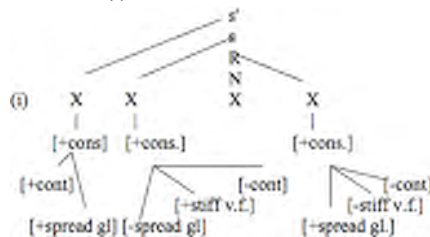

Why doesn't rule (15) apply in the structure in (i)? We propose that there is a constraint disallowing linked [+spread glottis] in clusters (see (37)). Given the regressive assimilation we have in clusters, application of rule (15) would produce such disallowed configurations. We can see this in the derivation in (ii):

3. Coda Neutralization

Putting aside for the moment the alternations due to Grassmann's and Bartholomae's Laws, we observe that there is devoicing and loss of aspiration in an obstruent in word-final position and before another obstruent. Crucially no such loss occurs before a sonorant consonant and before a syllabic peak.

Following Lombardi (1994), deaspiration, as well as the devoicing observed in word-final position and before obstruents, can be accounted for by hypothesizing that obstruents before a sonorant are in onset position and that the loss of laryngeal features observed in (3-6) is due to a neutralization process affecting obstruents in coda position. In particular, we assume that in Sanskrit, as in many other languages, only unmarked feature values are possible in coda position. In particular, we focus on unmarked laryngeal features, assuming that the natural rule in (18) is active in Sanskrit. This rule removes marked laryngeal features from an obstruent in coda position. Marked laryngeal features are identified by the independently needed marking statements in (19) (see (11):

(18)　　　　　　　　X　　　/　　____]s (where βG is a marked feature)
　　　　　　　　　　　|
　　　　　　　　-Sonorant
　　　　　　　　　　　|
　　　　　　　　Laryngeal
　　　　　　　　　　　‡
　　　　　　　　　　βG
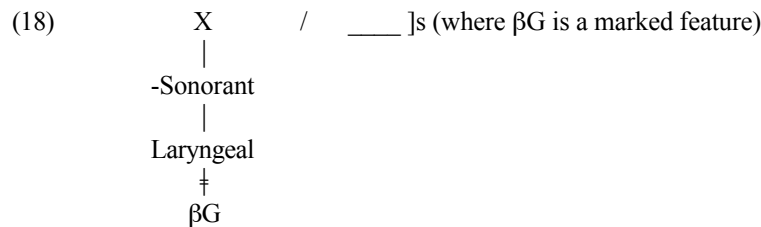
(19) a.　[-sonorant, -stiff vocal folds]　　(Marked features are underlined.)
　　b.　[-sonorant, +spread glottis]
　　c.　[-sonorant, +constricted glottis]

After the removal of the marked features, their unmarked counterparts are inserted. This is obtained by the convention in (20):

(20) Given the marking statement [αF, βG] where βG is marked, fill in -βG in a feature bundle that contains αF but no specifications for G.
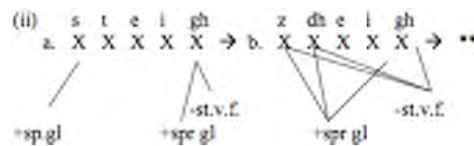
The configuration in (iib) cannot be repaired by removing the first link as required in IE (see below for discussion) because the voiceless must be [+spread glottis] (see (11av)). In addition voiced fricatives are not allowed in IE. The consequence is that this derivation will produce a disallowed output, and crash. Calabrese (2005) proposes that application of a rule leading to a crash is blocked. Under these conditions, application of (15) is blocked. Thus we have an explanation for why (15) does not apply in structures such as that in (i).

As a result of the marking statements in (18) and the convention in (20), a segment specified [-sonorant] will acquire the unmarked feature values [+stiff vocal folds, - spread glottis, - constricted glottis].

The delinking operation triggered by the rule in (18), in conjunction with the convention in (20), will account for the neutralization in laryngeal features we observe in the obstruents in coda position in (21):

(21) Voiced aspirate: *á-raːudh*   →   *áraːut*
     Voiceless aspirate: *á-praːth*   →   *ápraːṭ*
     Voiced unapirated: *á-bhed*   →   *ábhet*

The syllabic parsings in the forms in (22) with obstruents in coda position before other obstruents account for the neutralizations observed in them:

(22) Stop-obstruent clusters are heterosyllabic:

   raːdh-syá- → *raːdh . syá-* (→   (by (18)) → *raːt . syá-*)
   gr̥-ṇa-th-ti → *gr̥ . ṇath . ti* (→ (by (18)) → *gr̥ . ṇat . tí*)
   vid-tá → *vid . tá* (→   (by (18)) → *vit . tá*)

When obstruents appear before sonorants, they become part of the following onset as the examples in (23) illustrate. Being in onset position, neutralization does not apply:[7]

(23) Stop-sonorant clusters are tautosyllabic:

   dagh-ma- → *da . ghma-*
   rurudh-ré → *ru . ru . dhré*
   vivid-ré → *vi . vi. dré*
   raːdh-yá → *raː . dhyá-*
   vid-ya- → *vi . dya-*
   grath-ya- → *gra. thya-*

4.   Regressive Voicing Assimilation

Next we consider the rule of regressive voicing assimilation which is needed to account for the fact that a stop becomes voiced before a voiced stop, as in (24):

(24)   *marut-bhyas*   →   *marud-bhyas*

         The rule is given in (25):

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[7] Although the facts in (22) and (23) seem to indicate a clear heterosyllabic parsing of /C+s/-clusters, the situation is a little more complicated. As shown in Steriade (1988) (see also Calabrese (1998), the cluster /C+s/ in root initial position is syllabified as a complex onset, and thus patterns with clusters where a consonant is followed by a sonorant such as /Cy/, /Cw/, Cr/, etc., and not with clusters of falling sonority such as /s+ T/. A possible solution to the different behaviors of /C+s/ clusters is provided in Calabrese (1998) where it is hypothesized that certain syllabic constraints are deactivated only root internally. This could be the case of the constraint that disallows /C+s/-clusters. If this is correct, this cluster would be allowed in roots such as /kṣi/ 'dwell peacefully'. However, this cluster will not be allowed across morpheme boundaries as in /raːdh + syá-/.

(25)

The application of the rule of voicing assimilation creates a voiced obstruent in coda position, i.e. a configuration that should be disallowed by the rule in (25) that removes marked features in coda position. Now in this case the marked feature is also linked to the following consonant which occurs in onset position.

(26) *m a r u t   -bh y a s   m a r u d   -bh y a s*
       X X X X X   X X X X → X X X X X   X X X X
                │   │   \   │
       [+stiff v.f.][-stiff v.f.]   [-stiff v. f.]

This additional linking provides a clue to why the marked feature array is allowed in coda position after all. In the structure obtained by application of the voicing assimilation rule, the marked [-stiff vocal fold] feature is also linked to a consonant in onset position. This configuration is one that falls under the Uniformity Principle of Schein and Steriade (1986) (see also Hayes (1986)). This principle states that a constraint does not hold if it cannot apply exhaustively to its target configuration. This is the case in (26).

(27) The Uniformity Principle of Schein and Steriade (1986)
     (as reformulated in Calabrese (1999)):

     Given a node *n* and a set *S* consisting of all nodes linked to *n,* and given a rule or a constraint *T* , if *T* refers to *n* and any member of *S,* it must refer to all members of *S* to be active.

5. Grassmann's and Bartholomae's Laws

Aspiration appears on the second consonant of the root in (1a, b).[8] It appears on the first consonant of the root in (1c-g). These are cases of Grassmann's Law where root-final aspiration seems to be thrown back onto the first consonant of the root. (In (1f, g) the suffixes also begin with an aspirate.) In (1h) aspiration occurs after a consonant cluster at the end of the root, and not on any root consonant, thus appearing to have moved from the first consonant in the cluster to the second. These are instances of Bartholomae's Law.

---

[8] Aspiration does not appear in the consonant of the reduplicative prefix as in *bu-bodh-a* 'awake-3rd sg. perf.' We assume that the loss of aspiration in the case of this consonant is due to an independent process removing aspiration in the consonant of the reduplicative prefix (see Sag 1974, 1976; Schindler 1976). Evidence for this is the fact that in forms with a reduplicative prefix, aspiration throw-back stops at the root consonant (cf. *bubhutsati* 'awake-desiderative'). For the special behavior of the reduplicated forms of *dhā-* 'put' see Sag (1976), Schindler (1976: 628).

To account for the form in (1h) we need a rule that spreads the laryngeal features of the root-final voiced aspirate onto the following voiceless stop.[9] This rule (Bartholomae's Law) is given in (28).

(28)

Now observe that crucially the application of this rule creates a linked structure in which the marked features [+spread gl.] and [-stiff v.f.] are not only linked to a consonant in coda position, but also to a consonant in onset position. Given this configuration, rule (18) delinking marked features in coda position does not apply because of the Uniformity principle in (27): the second consonant in (28) is in onset position and thus the rule cannot apply exhaustively.

Now we have to account for why the feature [+spread glottis] is realized only in the second consonant in the cluster in (1h). Lombardi (1994) observes that the feature [+spread glottis] can be realized only once per cluster. In fact as Iverson and Salmons (1995) observe, the glottal opening associated with the feature [+spread glottis] has its own independent duration, with its peak occurring at a certain given time, which in a singleton corresponds with the release phase of the obstruent. *When this feature is linked to more segments, there is an articulatory difficulty in maintaining the open configuration of the glottis throughout the cluster.* To implement this observation formally, we assume that the marking statements assigning costs to different feature configurations include the constraint against multiply linked [+spread glottis] given in (29):

---

[9] As formulated in (34), Bartholomae's Law applies to both voiceless and voiced aspirates. The following examples support this:

(i) a. *dug-dhas*   /dhugh + thas/
         dug-dha   /dhugh + tha/
         alab + dhās   /a + labh + s + thās/
     b. *bodhi*   / bhaudh+dhi/ 'awake'–imperative
         dug-dhi   /dhaugh+dhi/ 'milk'-imperative

There are exceptions such as the form *attha*, or *bhud-dhvam* from *budh-dhvam* (see below for discussion.)

It cannot apply to a fricative such as /s/ (*pace* Schindler 1976, who argues that /s/ appears to have undergone Bartholomae's Law in Common Indo-Iranian.)

(29) *   X   X
       -sonorant   -sonorant
                \   /
              Laryngeal
                  |
           +spread glottis
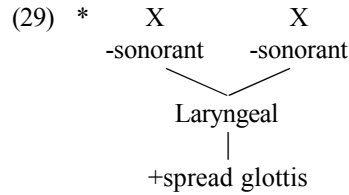
Thus rather than treat it as merely a phonetic fact, as was done by Iverson and Salmon, we assume that the temporal limitation on the glottal opening described above has a direct reflex in the marking statements that restrict the admissible feature configurations.

In Calabrese and Halle (1998), a number of exceptions to Grimm's Law in Germanic were accounted for by relying on the constraint in (29). Here we provide a brief discussion of these exceptions.

Grimm's Law is the traditional term for a number of changes in the obstruent system of the ancestor of the Germanic languages. In the first of these some of the [+stiff vf] stops were replaced in Germanic by their cognate continuants as illustrated in (30).

(30)
Latin	**Greek**	**Germanic**	**Baltic**	**Sanskrit**	
ped-	*pod-*	*fot*	*ped-*	*pad-*	'foot'
treːs	*tri-*	*θri-*	*tri-*	*tray-*	'three'
kruor	*kreas*	*hrar*	*kraujas*	*kravis*	'blood, raw'

Calabrese and Halle (1998) account for the changes in (30) by first supposing that Germanic was subject to a rule which aspirated voiceless stops. Following Iverson and Salmons (1995), Calabrese and Halle assume that the sound change accounting for the first step involves the assignment of the feature [+spread glottis] (aspiration) to voiceless stops, i.e., rule (31):

(31) [+stiff vocal folds] → [+spread glottis]/ [____, -continuant]

Subsequently, aspirated stops became fricative. We will not discuss this sound change here.

The problem now is to explain the exceptions to (31) illustrated in (32) where only the first component of the cluster is fricativized in Grimm's Law.

(32)
Latin	**Greek**	**Germ**	**Baltic**	**Sanskrit**	
octo	*oktoː*	*axtau*	*aston}i*	*ašta*	'eight'
Cf. also Lat *-spicio*		OHG	*spehen*		'spy'
	stella		*stern*		'star'
	scindo	Goth.	*skaidan*		'separate'
	neptis	OHG	*neftila*		'niece'
	piscis		*fisk*		'fish'

To obtain this, Calabrese and Halle rely on an independently needed rule that assimilates — regressively — all laryngeal features of the last obstruent in a cluster. This rule formulated in (33) — and probably identical to that discussed for Sanskrit in (25) — was already active in the proto-language, as shown by the examples of regressive voicing in (34) (Szemerenyi 1989: 108, quoted by Iverson and Salmons 1995) and was also active in Germanic (see the examples in (35) from Gothic):

(33) [-sonorant]   [-sonorant]
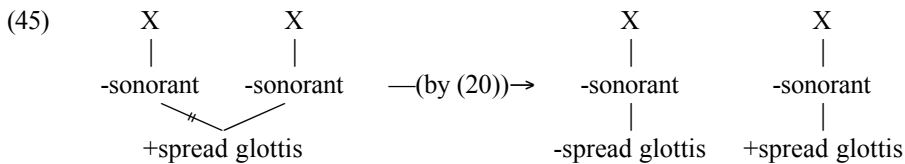
```
      Laryngeal        Laryngeal
```

(34) IE *yeug + to*   Sanskrit *yuk-tá* 'joined' < 'to tie, bind'
                          Greek *zeuk-tós* 'joined'
     IE *sed* 'sit':   *ni+sd+os > *nizdos* 'nest'
          pad- 'foot': Avestan fra-bda- 'fore part of the foot'

(35) *giβ -an* 'to give'   *fra-gif-t-s < fra-giβ-t-s* 'a giving'
     maɣ-um 'we may, can'   *mah-t-s < maɣ-t-s* 'could' (preterite)

The application of (33) to obstruent clusters affected by (31) in Germanic resulted in the linked structures in (36):

(36)   [+sonorant] [+sonorant]

```
            Laryngeal
               |
        [+spread glottis]
```

The application of (33) creates the structure disallowed by (29). We proposed that in Germanic, this disallowed structure was repaired as shown in (37) by delinking the feature [+spread glottis] from the non-initial segment.

(37) *   X   X
            | |
        -sonorant   -sonorant

```
            Laryngeal
               |
         +spread glottis
```

Delinking creates a structure in which there is no specification for the feature [spread glottis] in the non-initial member of the cluster. By virtue of convention (20) the unmarked feature [-spread glottis] is inserted here, as shown in (38):

(38)   X   X   X   X
           | | | |
       -sonorant -sonorant   —(by (20))→   -sonorant   -sonorant
                                                | |
           Laryngeal   Laryngeal   Laryngeal
              | | |
        +spread glottis   +spread glottis -spread glottis

The application of (31), (33), and (38) to the proto-Germanic forms in (39a) will produce the forms in (39c).[10] And thus we have an account for the exceptions in (32).

---

[10] Voiceless fricatives are [+spread glottis] given the following marking statement (see Calabrese and Halle (1998), Vaux (1998)): [+continuant, -spread glottis].

(39) a. *kaptas*   >>(by (31))>> b. $k^h ap^h t^h as$ >>(by(33) and (38))>> c. $k^h ap^h tas$
      a. $g^h astis$ b. $g^h ast^h is$ c. $g^h astis$
      a. $nak^w t$ b. $nak^{wh} t^h$ c. $nak^{wh} t$
      a. $steig^h e.ti$ b. $st^h eig^h et^h i$ c. $steig^h et^h$

6.   A Simplification in the Feature Geometry Representations

Up until now we have used simplified representations from the point of view of feature geometry. Let us now consider the way in which the delinking operation in (38) is implemented with respect to the featural content of nodes. Halle (1995), Halle, Vaux and Wolfe (2000) argued that spreading operations target only terminal nodes. Although they do not discuss this point, the same can be said of constraints and other operations such as delinking. This is what we assume here. In particular we propose that the constraint in (29) has its focus only on the association between terminal features and their dominant skeletal position. All other nodes are disregarded by the constraint. So when delinking correct violations of (29), it will affect only the terminal node [+spread glottis]. Therefore, it will disregard all other terminal features, in particular the other laryngeal features that may be shared by the two skeletal positions. Notice that from the representational point of view, in order to obtain this result in terms of feature geometry we have to assume that there is an automatic cloning of the laryngeal node as shown in (40):

The unaspirated consonant in (40) results from the delinking of [+spread glottis] and its automatic replacement by the unmarked [-spread glottis] in accordance with the convention in (20). This is a consequence of the fundamental status played by the terminal features in phonological representations. Non-terminal features like the laryngeal node in (40) play only a classificatory role and therefore can be automatically readjusted. Therefore, intermediate nodes, except the root node that is necessary to identify the major class feature of the segment, do not play a role in operations affecting the relation between terminal features and skeletal positions. The representations we are using therefore can be simplified as in (41) to make this relation explicit:

(41) Skeletal positions: X

     Roots: Root

     Terminal features: A   B   C

Consider the change in (42). (It occurs in (39a) $k^h ap^h t^h as \rightarrow k^h ap^h tas$)). Given (41), it can be simplified as in (43):

(42)　　　ph　　　　　th　　　→　　　　ph　　　　　　t
　　　　　X　　　　　X　　　　　　　　X　　　　　　X

　　　　-son　　　　-son　　　　　　-son　　　　　-son

　　　　　Laryngeal　　　　　　　Laryngeal　　　Laryngeal

　　　　　　　+stiff vf　　　　　　　　+stiff vf.
　　+spread glottis　　　　　　+spread glottis　　-spread glottis

(43)　　　ph　　　　　th　　　→　　　　ph　　　　　　t
　　　　　X　　　　　X　　　　　　　　X　　　　　　X

　　　　-son　　　　-son　　　　　　-son　　　　　-son

　　+stiff vf　　　　　　　　　　　　　　　+stiff vf.
　　　　　　+spread glottis　　　　+spread glottis　-spread glottis

The unaspirated /t/ in (43) results from the loss of [+spread glottis] and its automatic replacement by the unmarked [-spread glottis] in accordance with the conventions in (20). From now on I will use these simplified representations

7.　Sanskrit Again

Let us turn back to Sanskrit again. Observe that the application of Bartholomae's Law in (28) creates exactly the structure disallowed by (29). We can now propose that the the difference between Sanskrit and Germanic is in the type of repair occurring in the two languages. In particular, whereas in Germanic it is the second member of the cluster disallowed by (29) to be the target of delinking, in Sanskrit it is the first member to be the target of delinking

(44)　*　　　X　　　　　　X
　　　　　-sonorant　　　-sonorant
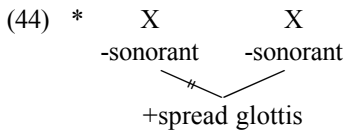
　　　　　　　+spread glottis

The further application of the convention in (20) will insert the unmarked feature [-spread glottis to its feature bundle, as shown in (45):

(45)　　　　X　　　　　X　　　　　　　　　X　　　　　　X
　　　　　　|　　　　　|　　　　　　　　　|　　　　　　|
　　　　-sonorant　　-sonorant　　—(by (20))→　　-sonorant　　　　-sonorant
　　　　　　　　　　　　　　　　　　　　　　|　　　　　　|
　　　　　　+spread glottis　　　　　　-spread glottis　　+spread glottis

Let us consider the form *ruddha* 'obstruct-prt'. Its underlying form is given in (46).
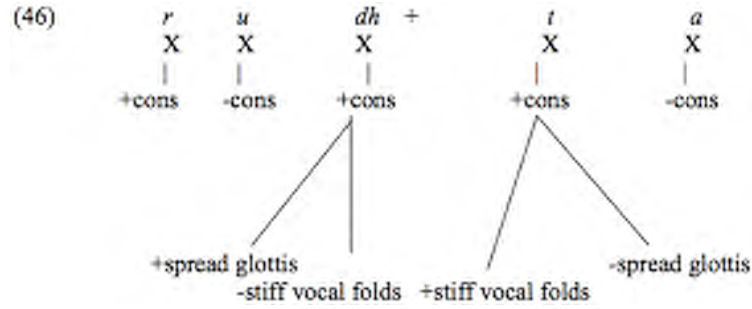
(46)

r	u	dh	÷	t	a
X	X	X		X	X

+cons -cons +cons   +cons -cons

+spread glottis   -spread glottis
-stiff vocal folds +stiff vocal folds

Bartholomae's Law applies spreading the terminal features of the laryngeal node of the voiced aspirate to the stop to its right, as in (47):
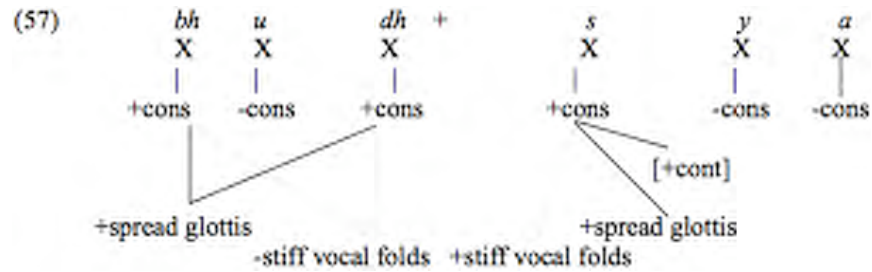
(47)

r	u	dh	+	t	a
X	X	X		X	X

+cons -cons +cons   +cons -cons

+spread glottis   -spread glottis
-stiff vocal folds +stiff vocal folds
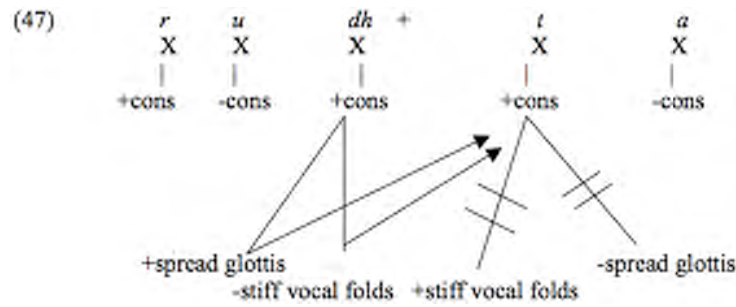
(44) now applies, delinking the first feature [+spread glottis]. This result in the structure in (49):

(48)

r	u	dh	+	dh	a
X	X	X		X	X

+cons -cons +cons   +cons -cons

+spread glottis
-stiff vocal folds

(49)

r	u	d	+	dh	a
X	X	X		X	X

+cons -cons +cons   +cons -cons

-spread glottis   +spread glottis
-stiff vocal folds
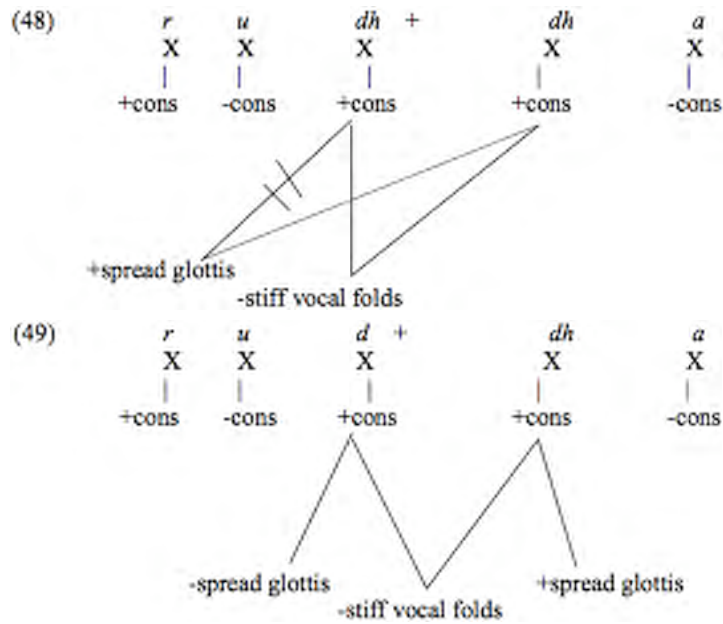
Thus we account for why the feature [+spread glottis] is realized only in the second consonant after the application of Bartholomae's Law.

We now propose that Grassmann's Law is an instance of the same delinking we see in (48). Let us assume that diaspirate roots are underlyingly characterized by having a common laryngeal node linked to the stops in the onset and coda of the root, as shown in (50) (from now on, to make the representations more clear, lines associated with the feature [stiff vocal folds] are dashed. Those associated with the feature [spread glottis] are solid).

(50) Underlying representation of diaspirate roots:
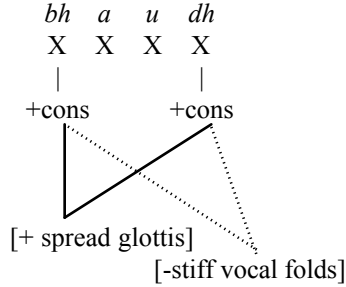
We account for Grassmann's Law in this fashion: when [+spread glottis] is delinked as in (44), it is always and only the last link that survives. This is shown in (51) in the case of the example *bodhati*:

(51)

(52)
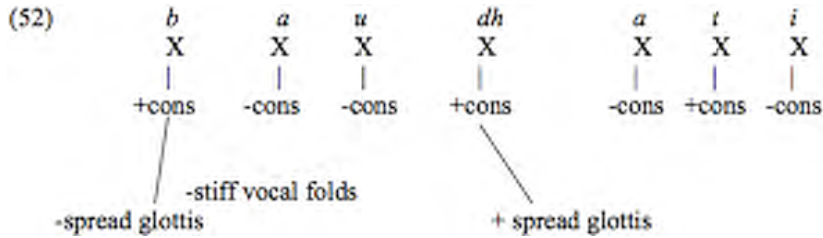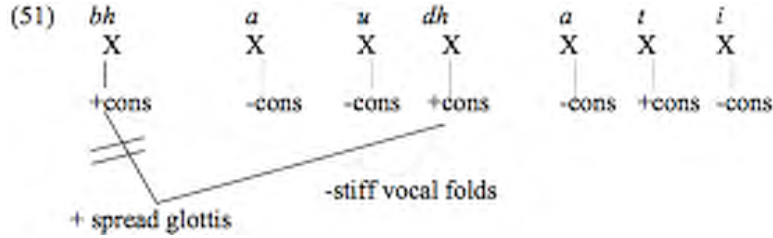
We turn to the form *buddha*. Its underlying form is given in (53):
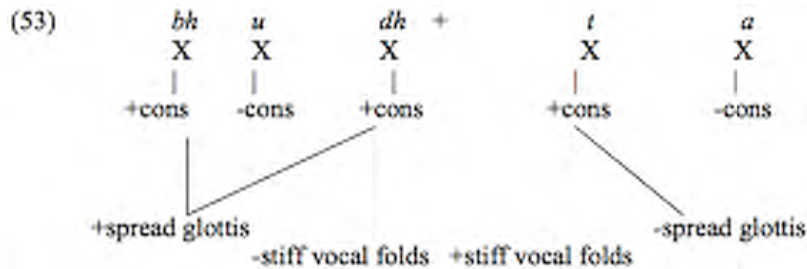
(53)

Bartholomae's Law applies spreading the terminal features of the laryngeal node of the voiced aspirate to the stop to its right as in (54):
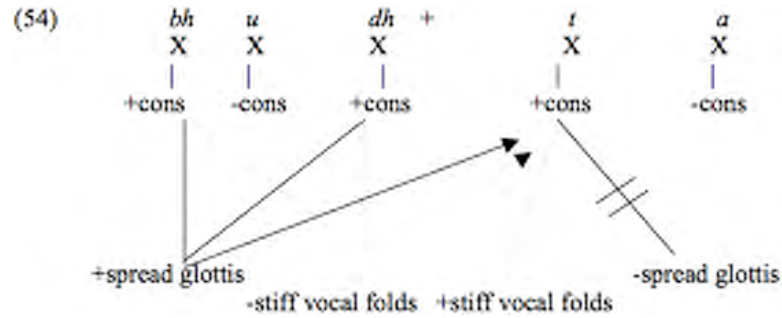
(54)

	bh	u	dh	+		t		a
	X	X	X			X		X
	+cons	-cons	+cons			+cons		-cons

+spread glottis   -spread glottis
-stiff vocal folds   +stiff vocal folds

(44) now applies, delinking all the links of the feature [+spread glottis] except the last one:

(55)

	bh	u	dh	+	dh		a
	X	X	X		X		X
	+cons	-cons	+cons		+cons		-cons

+spread glottis
-stiff vocal folds
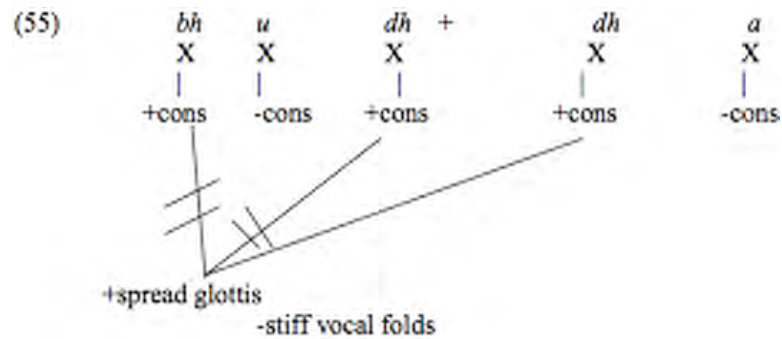
This results in the structure in (56) which again accounts for the surface shape of this form.

(56)

	b	u	d	+	dh		a
	X	X	X		X		X
	+cons	-cons	+cons		+cons		-cons

-spread glottis   +spread glottis
-stiff vocal folds
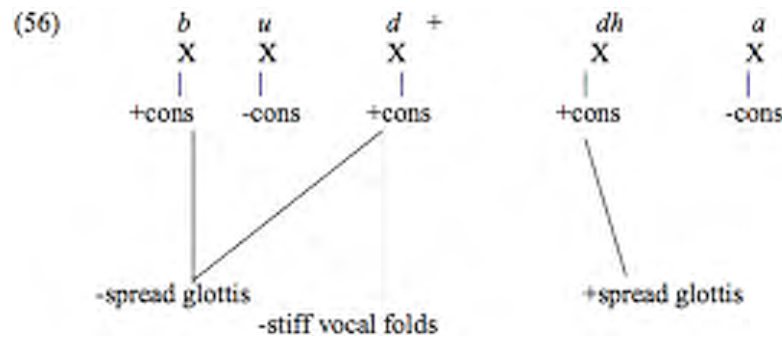
Let us now consider the form *bhutsyati*. We start with the underlying representation in (57):

(57)

	bh	u	dh	+	s	y	a
	X	X	X		X	X	X
	+cons	-cons	+cons		+cons	-cons	-cons

[+cont]

+spread glottis   +spread glottis
-stiff vocal folds   +stiff vocal folds

Bartholomae's Law cannot apply because it targets only stops. In (57) we have a voiced aspirate in coda position. Rule (18) delinking marked features in coda therefore applies, as in (58). Unmarked features are then inserted by (20) as in (59):[11,12]

(58)

(59)
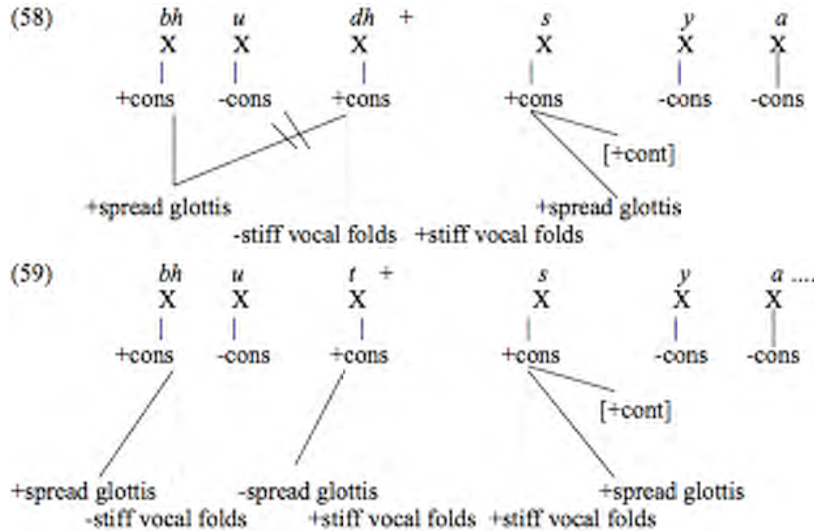
Let us derive the form *dugdhi* 'milk, derive-Imperative'. The root /dhaugh/ is a diaspirate root as shown by a form such as *dhoksyate* 'future'. Given the underlying representation in (60), Bartholomae's Law applies vacuously and we obtain (61):

---

[11] Exceptions such as that in (i) where Bartholomae's Law did not apply can now be accounted for in a straightforward way.

  (i) *dhaktam* /dhagh+tam/ (exception to Bartholomae's Law)
       (cf. *inttām* /indh+tam/, also an exception to Bartholomae's Law)

Since Bartholomae's Law did not apply, the linked structure preventing the application of the rule in (18) is not created. The root final voiced aspirate is in coda position. The rule delinking marked features in coda therefore applies. The marked features of this consonant are then delinked and replaced with unmarked features, thereby obtaining a voiceless unaspirated stop.

[12] Vedic texts display alternants of diaspirate roots in which aspiration is removed both from the coda and the onset consonant of the root before suffixes beginning with /s/; so for example we have *dakṣat, adukṣat* as alternant of *dhakṣat* 'burn-aorist', *ad-hukṣat* 'milk-aorist' (see Schindler (1976: 631) for a list). The simplest hypothesis to account for these alternants is to assume that they belong to an innovative dialect in which the laryngeal features [-stiff v.f., +spread glottis] of "diaspirate" roots are not linked to both root onset and coda consonant, but only to the coda consonant. Therefore when there is laryngeal neutralization before /s/, there will not be any aspiration "throw back". Given that these alternants are not found in later stages of Sanskrit, we have to assume that this dialect was little influential and eventually died out.
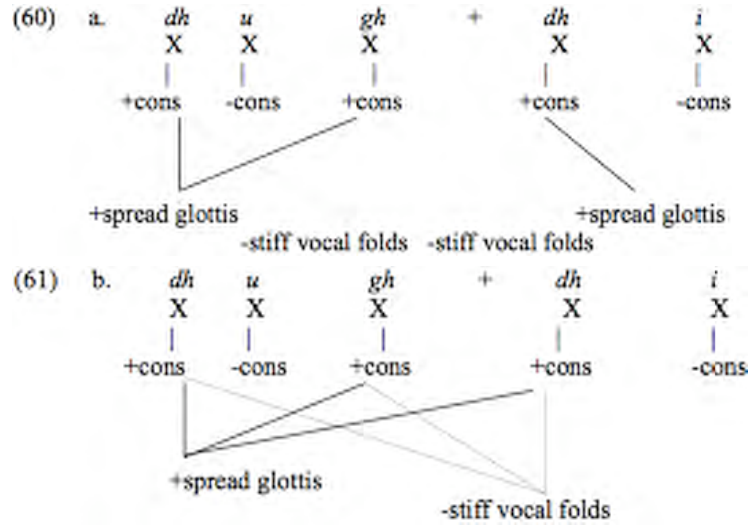
(60) a.
$$
\begin{array}{ccccccc}
dh & u & & gh & + & dh & i \\
X & X & & X & & X & X \\
| & | & & | & & | & | \\
\text{+cons} & \text{-cons} & & \text{+cons} & & \text{+cons} & \text{-cons}
\end{array}
$$

+spread glottis   +spread glottis
-stiff vocal folds -stiff vocal folds

(61) b.
$$
\begin{array}{ccccccc}
dh & u & & gh & + & dh & i \\
X & X & & X & & X & X \\
| & | & & | & & | & | \\
\text{+cons} & \text{-cons} & & \text{+cons} & & \text{+cons} & \text{-cons}
\end{array}
$$

+spread glottis
-stiff vocal folds

(44) now applies, delinking all the links of the feature [+spread glottis] except the last one:

(62)
$$
\begin{array}{ccccccc}
dh & u & & gh & + & dh & i \\
X & X & & X & & X & X \\
| & | & & | & & | & | \\
\text{+cons} & \text{-cons} & & \text{+cons} & & \text{+cons} & \text{-cons}
\end{array}
$$

+spread glottis
-stiff vocal folds

(63)
$$
\begin{array}{ccccccc}
d & u & & g & + & dh & i \\
X & X & & X & & X & X \\
| & | & & | & & | & | \\
\text{+cons} & \text{-cons} & & \text{+cons} & & \text{+cons} & \text{-cons}
\end{array}
$$

-spread glottis   +spread glottis
-stiff vocal folds
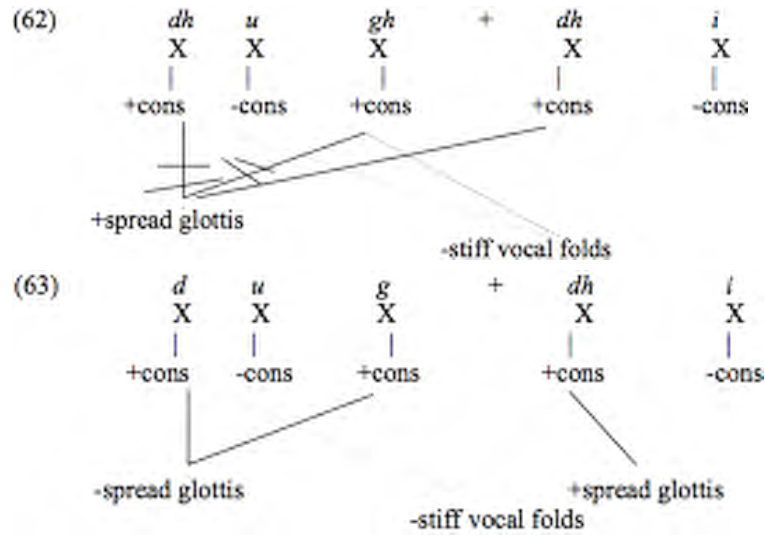
We assume that the forms in (64) are exceptions to Bartholomae's Law.

(64) a. *bhudbhis*   /bhudh + bhis/
     b. *dhugdhve*   /dhugh + dhve/

These forms then behave like *bhotsyati*.

(65)
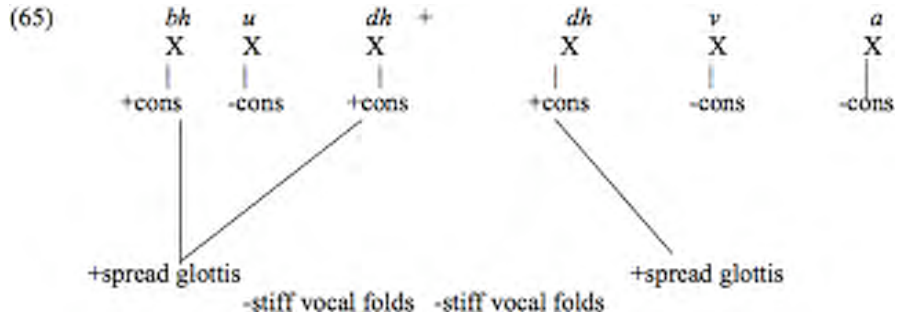
Since Bartholomae's Law does not apply, a linked structure preventing the application of the rule in (18) is therefore not created. The root final voiced aspirate is in coda position. Rule (18) delinking marked features in coda therefore applies. Therefore we get (66):

(66)
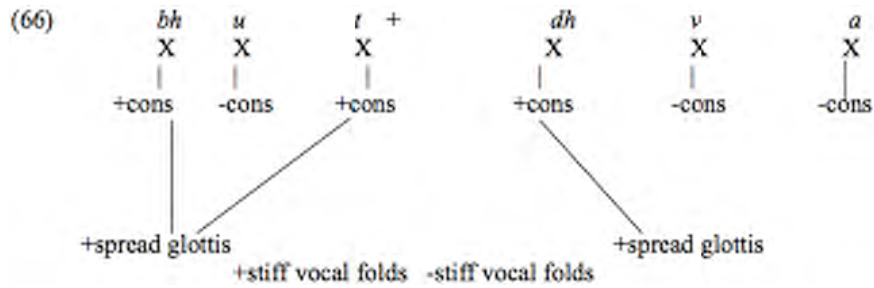
Then regressive voicing assimilation in (24) changes it to a voiced consonant, and we obtain the correct surface form as in (67):

(67)
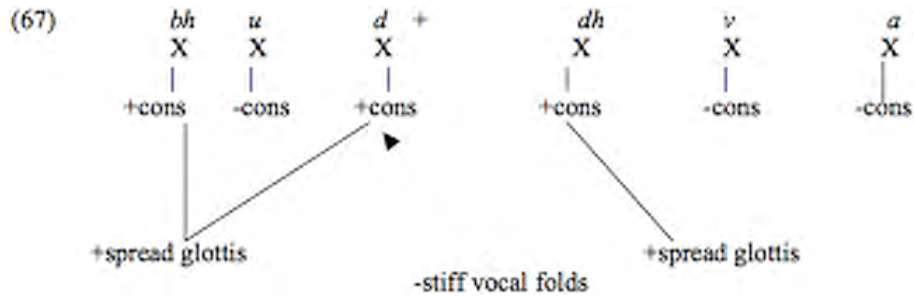
A successful account of all of the relevant forms involving Grassmann's and Bartholomae's Laws is therefore achieved.

7. Grassmann's Law in PIE

Correspondences like those in (68) show that Grassmann's Law did not apply in the proto-language and that we have to reconstruct roots containing voiced aspirates both in the onset and coda of the root (cf. Mayrhofer (1986)).

(68) English   Sanskrit
      bind   *bandh*
      daughter   *duhitar*
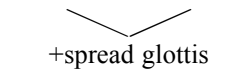
(69)   PIE: *bhendh*
                dhughHter

If we do not assume the reconstructions in (69), in fact, we should find [pind] and [taughter] in English--instead of bind and daughter-- with voiceless consonants in word initial position because normally PIE (Skt) voiced unaspirated consonants correspond to Germ. voiceless consonants.
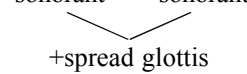
(70) | **Latin** | **Greek** | **Germ** | **Baltic** | **Sanskrit** | |
|---|---|---|---|---|---|
| *duo* | *duo:* | *twai* | *div* | *dva:u* | 'two' |
| *ed-* | *ed-* | *et-* | *ed-* | *ad-* | 'eat' |
| *genu* | *gonu* | *kni* | | *janu* | 'knee' |
| *iugum* | *dzugon* | *yoke* | *jungas* | *yuga* | 'yoke' |

To account for the fact that Grassmann's Law did not apply in the proto-language, we propose that the constraint which disallows the linking of the feature [+spread glottis] to multiple consonants has two different occurrences depending of whether or not the consonants are string adjacent:

It is a prohibition — which can never be deactivated — if the two consonants are adjacent. (a double asterisk marks a prohibition):

(71) ** X_1 X_2 (where X_1 and X_2 are adjacent)
            -sonorant   -sonorant
                        \diagdown   \diagup
                        +spread glottis

It is a marking statement — which can be deactivated — if the two consonants are not adjacent.

(71) * X_1 X_2
            -sonorant   -sonorant
                        \diagdown   \diagup
                        +spread glottis

(72) was deactivated in the the proto-language where only the more restrictive prohibition in (71) was active as in any other language. This is the situation that was preserved until the elimination of the voiced aspirate stops in the various IE languages.

However, the marking statement in (72) became active in Sanskrit (and in Greek), and therefore it merged with the prohibition in (71) with the effects we have discussed above.

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Encomium
Samuel Jay Keyser
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I belong to a select club of one. There is one entrance requirement. You must have given Alan Prince his first job in linguistics. I joined that club in the Fall of 1975 at the University of Massachusetts at Amherst and am still a proud member. Alan hit the field running and his career (to date) has culminated in the seminal role he has played in the creation, development and dissemination of Optimality Theory.

My most valued interactions with Alan—alas, too long ago—are two. First, I remember the long conversations we had about the poetry of Wallace Stevens shortly after he joined the University of Massachusetts department. His insight, his fertile imagination and his encyclopedic knowledge of poetry peeled layer after layer away from the surface of that great poet, much to my personal delight and edification. Second, I remember the film series that he was instrumental in starting. Japanese films were featured and the highlight of each showing was Alan's commentaries. I will never forget his account of Kihachi Okamoto's "The Sword of Doom," starring Toshiro Mifune. It was one of the most insightful film critiques I have ever heard. All of this is by way of recognizing that Alan's omnivorous intelligence has many facets, each of which is honored, if only partially, by the contributions to this volume.