4 Laryngeal features

> Les changements phonétiques sont les manifestations et les réalisations de tendances, que la langue a contractée au cours de sa vie antérieure. Ces changements sont désignés par le nom de *lois phonétiques*.
>
> Grammont (1933: 166)

4.1 Phonological features and laryngeal features

If there is one point of agreement within phonetic and phonological theory, it is that the segments which compose speech are not indivisible primitive units of speech. Instead, the general view is that segments are the simultaneous realization of smaller units, known as *features*. Features play a significant role in defining sound change and sound patterns. At the phonetic level, there are potentially gradient and potentially imperceptible *phonetic features*; at the phonological level, there are *distinctive features* which are typically privative (single-valued) or binary-valued, and which define contrasts which are typically perceptible to all human newborns (Werker and Pegg 1992). These distinctive features are the basis of all attested phonological contrasts. Two primary arguments exist for distinctive features. One argument is that they correspond quite closely to innate perceptual categories demonstrated in newborns and young children (9.1). Another argument is that they allow the statement of what appear to be significant generalizations across sound patterns.

In this chapter, characteristic patterns of laryngeal feature distribution are investigated.[1] Laryngeal features are those which characterize the state

[1] Languages on which generalizations are based include: Lithuanian, German, Frisian, Sanskrit, Russian, French, Catalan, English, Attic Greek, Polish, Maithili, Lamani (Indo-European); Kiowa (Kiowa-Tanoan); Yokuts, Kashaya, Miwok, Klamath, Tsimshian, Nez Perce; Afar (Cushitic); Dinka (Nilotic); Ngizim (Chadic); Korean; Hungarian (Finno-Ugric); Kolami (Dravidian); Yateé Zapotec (Otomanguean); Tamazight Berber (Afro-Asiatic/Berber); Arabic, Syrian, Eastern, Moroccan, Iraqi Arabic (Afro-Asiatic/Semitic); Totontepec Mixe (Mixe-Zoque); Nhanda (Pama-Nyungan); Lac Simon (Algonquian); Wantoat, Kalam (Papuan); Sre, Pacoh (Mon-Khmer); Chepang,

of the larynx or vocal folds, and the acoustic and perceptual features associated with these states. Though it is necessary to distinguish dozens of phonetic categories which contrast gradient voice onset times, degrees of laryngealization, and pulmonic versus laryngeal airstream mechanisms (Gordon and Ladefoged 2001), for the purposes of describing contrasts in phonological segment inventories, only three phonological features appear necessary. These features are often labeled as [voiced], [spread glottis], and [constricted glottis].[2] While labeling and precise definitions of these features may be disputed, there are two aspects of the feature system which are non-negotiable. First, phonological features are distinct from gradient phonetic properties, and typically reflect categories which have multiple distinct phonetic instantiations or cues. Second, no reference is made in phonological systems to non-contrastive features (e.g. the release of stops, 2 ms of voice-onset time, laminal interdental versus laminal dental, etc.) Each of these properties is integral to the explanations provided for typical cases of regular sound change. Because phonological features are distinct from gradient phonetic properties, and there is typically no one-to-one relationship between a phonological feature or category and a single phonetic characteristic, reinterpretations of the phonetic signal in the form of slight shifts of whole categories within the psycho-acoustic space are expected.

Within a single language, identical phonological feature specifications can be associated with highly distinct phonetic features depending on phonological context, or on other segment-internal feature specifications. Consider the phonetic contrast between pre- and post-aspirated segments. Though these two sounds clearly constitute different acoustic and auditory categories, in Icelandic (Thráinsson 1978), regular alternations condition pre- and post-aspirates, which are in complementary distribution. In other languages, like Twampa (Thelwall 1983; 334) post-aspirates have optional pre-aspirated variants in certain contexts. The same sort of phonetic variation characterizes segments defined as [constricted glottis]. In Klamath (Barker 1964; Blevins 1993a), sonorants with this feature are pre-glottalized, while obstruents are realized as ejectives. For more examples of this kind, see Kingston (1990). The

Mikir, Sherpa (Tibeto-Burman); Lushootseed, Twana, Bella Coola, Montana Salish, Shuswap (Salishan); Palauan, Marshallese (Austronesian); Nootka, Kwakiutl (Wakashan); Haida (isolate); Mbe (Niger-Congo/Bantu), as well as others mentioned in the text. This set includes 52 languages from 22 different language families.

2 Here I do not include laryngeal "tone" features. For an overview of the relationship between laryngeal features and tone, see Yip (1995: 484–88). On the evolution of tonal systems from F_0 perturbations associated with consonantal laryngeal features, see Hombert et al. (1979). And for phonological systems where tone features interact with other laryngeal features, see Hyman (1973).

phonological identity of pre- and post-aspiration, and of pre-glottalization and post-glottalization (or ejection), is strongly supported by the fact that no languages are reported to contrast segments with respect to these dimensions alone. Our starting point for the investigation which follows, then, is that a limited number of phonological categories or segment types are defined by a limited set of phonological features.

4.2 The phonetic basis of sound patterns

Since the introduction of distinctive features into phonological theory, the majority of phonotactic constraints have been stated in terms of natural classes defined by distinctive features. One fundamental observation which emerges from the cross-linguistic study of the distribution of laryngeal features is that segments with identical phonological feature representations may have dramatically different patterns of distribution. For example, there is a strong cross-linguistic preference for post-aspiration of consonants to occur pre-vocalically, while pre-aspiration of consonants is generally found post-vocalically. Accounting for this general type of distributional pattern is problematic for most phonological approaches, since pre-aspirates and post-aspirates are non-contrastive, and therefore are assumed to have identical phonological representations. One might think of this as an isolated problem, relating only to the characterization of aspiration, but the same problem occurs again and again: recurrent phonotactic patterns seem directly related to *non-distinctive* properties of sound patterns, and yet, phonological characterization of these patterns must be stated without reference to non-distinctive properties, missing important generalizations.

How can this problem be overcome? Two logical alternatives present themselves. One possibility is to abandon a pure phonological feature system by introducing phonetic detail into phonological representations. This is the position taken, for example, by Steriade (1993, 1999a), Kirchner (2000), and Flemming (2001). In these accounts, sound patterns are defined with direct reference to phonetic features as well as phonological ones. This alternative eliminates any principled distinction between phonological and phonetic representations, or phonological and phonetic features, and attempts to build phonetic explanations into phonological representations and constraints themselves. A second alternative, and the one defended throughout this book, is to maintain a pure categorical phonology, free of phonetic detail. This view of phonology, similar to that conceived of by the Prague school, represents all and only the features, segments, and prosodic categories which are *contrastive* in the world's languages. Within Evolutionary Phonology, the phonotactic regularities exhibited by synchronic phonologies appear to be sensitive to phonetic detail because they are arguably, in many cases, the transparent result of phonetically motivated sound change. Since phonetically motivated sound change is well evidenced in the historical record, and can be simulated in the laboratory, relying on such factors to explain recurrent relationships between feature distribution and non-distinctive properties of speech appears to be the null hypothesis.

A primary argument for Evolutionary Phonology over alternative approaches is that phonetically motivated sound change is already accepted as one explanation for properties of synchronic sound systems. Any model which incorporates phonetic detail into phonological systems in order to explain synchronic regularities is essentially duplicating an explanation which already exists in the diachronic dimension. Under this account, there is no pre-determined set of phonological constraints in the mind of the speaker which gives rise to recurrent sound patterns. Rather, the phonotactic regularities examined in this and following chapters are *emergent universals* in the sense of Deacon (1997: 115–16):

> Grammatical universals exist, but . . . their existence does not imply that they are prefigured in the brain like frozen evolutionary accidents. In fact, . . . the universal rules or implicit axioms of grammar aren't really stored or located anywhere, and in an important sense, they are not *determined* at all. Instead . . . they have emerged spontaneously and independently in each evolving language, in response to universal biases in the selection processes affecting language transmission. They are convergent features of language evolution in the same way that the dorsal fins of sharks, ichthyosaurs, and dolphins are independent convergent adaptations of aquatic species. Like their biological counterparts, these structural commonalities present in all languages have each arisen in response to the constraints imposed by a common adaptive context. Some of the sources of universal selection on the evolution of language structures include immature learning biases, human mnemonic and perceptual biases, the constraints of human vocal articulation and hearing . . . to name a few. Because of these incessant influences, languages independently come to resemble one another, not in detail, but in terms of certain general structural properties . . .

In the following section I summarize ways in which languages independently come to resemble one another in terms of the distribution of laryngeal features.

4.3 Recurrent patterns of laryngeal feature distribution

The distribution of distinctive laryngeal features on consonants is severely limited in many languages. Obstruent voicing, aspiration, and ejection are often limited to certain positions, while distinct distributional constraints are found for sonorant voicelessness and sonorant laryngealization. As documented by Lombardi (1991), Steriade (1999a), Fallon (2002), and Blevins (2003a) among others, there is general similarity across languages with respect to: (i) the neutralizing feature or features; (ii) the positions in which neutralization occurs; (iii) the direction of neutralization; and (iv) distinct neutralization patterns for laryngeal features of obstruents and sonorants.

In (1)–(3) I summarize some of these recurrent patterns with respect to their phonetic status as release features, realized at consonant release, or closure features, realized at the onset of consonant closure.

(1) Release feature pattern: obstruent voicing, obstruent post-aspiration, obstruent ejection
- (i) PHONETIC FEATURES: post-aspiration, post-glottalization, ejective release, release cues for voicing (burst strength, VOT, F_0 values, F_1 values)
- (ii) PHONOLOGICAL FEATURES: [voiced], [spread glottis], [constricted glottis]
- (iii) COMMON POSITIONS OF CONTRAST: before sonorants
- (iv) COMMON POSITIONS OF NEUTRALIZATION: before obstruents, word-finally
- (v) COMMON DIRECTION OF NEUTRALIZATION: neutralization is either
  - a. to the voiceless unaspirated member of the series, or
  - b. in obstruent clusters, the result of regressive assimilation

(2) Closure feature pattern: sonorant pre-glottalization
- (i) PHONETIC FEATURE: pre-glottalization
- (ii) PHONOLOGICAL FEATURES: [−syllabic, +sonorant, constricted glottis]
- (iii) COMMON POSITIONS OF CONTRAST: after vowels
- (iv) COMMON POSITIONS OF NEUTRALIZATION: after consonants, word-initially
- (v) COMMON DIRECTION OF NEUTRALIZATION: to the plain voiced member of the series

(3) Closure feature pattern: obstruent pre-aspiration
- (i) PHONETIC FEATURE: pre-aspiration
- (ii) PHONOLOGICAL FEATURES: [−sonorant, −continuant, spread glottis]
- (iii) COMMON POSITIONS OF CONTRAST: after vowels, sometimes after sonorant consonants

(iv) COMMON POSITIONS OF NEUTRALIZATION: after obstruents

(v) COMMON DIRECTION OF NEUTRALIZATION: neutralization is either

a. to the voiceless unaspirated member of the series, or
b. in obstruent clusters, the result of progressive assimilation

No phonological system is known to contrast post-aspirated stops with their pre-aspirated counterparts. Nevertheless, this phonetic difference appears to determine the general sound patterns of aspirated stops both within and across languages. Compare the common patterns involving post-aspiration, a release feature, in (1), with those of pre-aspiration, a closure feature, in (3). The patterns are near mirror images of each other. Post-aspirates contrast most widely in pre-vocalic position, while pre-aspirates are most likely to contrast in post-vocalic position. The cross-linguistic regularities in this distribution are problematic for phonological theory since all aspirated oral stops will have the same basic feature representation.

The patterns in (1) and (2) are also near mirror images. Compare ejective obstruents and their distribution with pre-glottalized sonorants. Though both segment types are characterized by the same distinctive feature, [constricted glottis], neutralization of ejection is common before obstruents and word-finally, while neutralization of glottalized sonorants is typical word-initially and after consonants. As far as I am aware, there are no reported cases of ejectives neutralizing to plain stops word-initially or post-consonantally, highlighting the distinctive patterns of contrast for closure and release features documented by Steriade (1999a).[3]

Perhaps the most well-known and well-studied examples of laryngeal neutralization involve obstruent devoicing. Given a language where voiced and voiceless obstruents contrast in some environments, there are typically other environments in which voicing is non-contrastive. In unrelated languages across the world we find that the voicing contrast is neutralized for obstruents, that this neutralization tends to occur word-finally and/or in pre-obstruent position, and that neutralization in word-final position is to the voiceless phone, while neutralization in pre-obstruent position is typically either to the voiceless phone, or subject to regressive voice assimilation. This pattern is included in (1).

The emergent sound patterns summarized in (1)–(3) do not appear to be the result of chance occurrences. Word-final neutralization of laryngeal release features is common, while word-initial neutralization of the same

[3] Context-free shifts from ejective to plain stops are reported in Fallon (2002, chapter 3).

release features is unattested. At the same time, word-initial neutralization of sonorant pre-glottalization is common, while word-final neutralization of pre-glottalization is rare. The significance of these distinct patterns of contrast and neutralization cannot be overstated. Phonological features show distinct patterns of distribution which appear to be dependent, at least in part, on their phonetic realization. In 4.4, historical phonetic explanations are proposed for these common and recurrent sound patterns. However, before turning to these, it will be useful to briefly review how and why such patterns are best characterized in terms of parallel evolution.

General accounts of similarity were reviewed in 2.4. Recurrent sound patterns may be the result of shared inheritance, convergent evolution, parallel evolution, or diffusion through language contact. For the majority of languages included in the surveys cited above, diffusion can be ruled out as the source of similarity. Many of these languages are spoken on different continents or islands, with no evidence of contact between them. For example, there is no evidence of linguistic contact between Korean speakers, Dinka speakers of Saharan Africa, Wantoat speakers of New Guinea or Klamath speakers of south-central Oregon, and yet all of these languages have sound patterns of the type summarized in (1). Diffusion of laryngeal sound patterns from neighboring languages can often be ruled out as well. For example, although Yurok is spoken close to other languages with glottalized sonorants, the same languages show no evidence for the Yurok pattern of neutralization conforming to (2). As a consequence, the sound patterns on which the generalizations in (1)–(3) are based are ones which appear to have evolved spontaneously many times in the natural course of language change.

Ruling out diffusion as an explanation for these common sound patterns still leaves open the possibility that they are nothing more than chance resemblances. As Blust (1990: 24) notes:

> Ideally, in evaluating the role of chance as an explanation we should have access to a statistical model which states how many times a given sound change might be expected to occur in relation to the null hypothesis. Unfortunately, no such model is available, and we are consequently forced to fall back upon an impressionistic statement.

This is still the case over a decade later, and we are forced to rely on linguistic intuitions as to what constitutes "more than chance frequency" for a given pattern. However, if chance were entirely responsible for the patterns of laryngeal feature distribution just summarized, then we would expect similar frequencies for other "chance" events. If there is no principled difference between word-final devoicing and word-final voicing, both being the possible result of chance events, then how are we to explain the high frequency of the first pattern in contrast to the low frequency of the second? Likewise, if the association between release versus closure features and positions of contrast is the result of chance, what could possibly explain the common neutralization of post-aspiration in word-final position, in contrast to the rarity of rules neutralizing pre-aspiration in precisely the same environment? If common sound patterns are the result of phonetically motivated sound change, then a starting point for a statistical model is the observation that sound patterns which can result directly from phonetically motivated sound change will be more common than ones which cannot, and those which have multiple sources in sound change will be more common than those with single sources. This starting point will allow us to account for the very high frequency of word-final devoicing in contrast to the high frequency of word-final de-aspiration, and the apparent absence of regular word-final voicing.

With diffusion and chance incapable of explaining the recurrent nature and high frequency of the sound patterns in (1)–(3), we are left to conclude that these patterns of laryngeal feature distribution are instances of shared inheritance or parallel evolution. A great many of the genetic relationships among the world's languages have been established by use of the comparative method. Widely agreed-upon genealogies exist for many language families, including Algonquian, Austronesian, Indo-European, Mayan, Niger-Congo, Semitic, and Sino-Tibetan, to name just a few. Given well-understood genetic relationships among languages, it is often possible to determine whether or not a particular sound pattern is the result of direct inheritance, or not. While many similar patterns of laryngeal feature distribution *are* the simple result of shared inheritance, a great many are not. Historical records of Sanskrit allow us to reconstruct ancient patterns of laryngeal feature distribution, and to see the extent to which these have been directly inherited by modern Indic languages like Gujarati and Punjabi. But for each case of direct inheritance, there are near-identical patterns of laryngeal feature distribution in an unrelated language or language family. Klamath, Korean, Dinka, and Wantoat were mentioned earlier. Genetic affiliations of Klamath and Korean are debated, but each language certainly qualifies as independent stock from any of the other languages with similar sound patterns. Dinka is a Nilotic (Nilo-Saharan) language of the Sudan, and Wantoat, a language of Morobe Province, Papua New Guinea, has been assigned to the Trans-New Guinea phylum. Similarities between Proto-Indo-European, Gujarati, and Punjabi might be the result of direct inheritance, but those between Indic, Klamath, Korean, Dinka, and Wantoat are not.

The strongest evidence for parallel evolution, however, are cases where it can be demonstrated that a particular sound pattern was not a feature of the mother tongue, and that it is the result of an innovation. The reconstruction of languages and language families has uncovered thousands of sound changes, which, when studied closely, provide the empirical base for parallel evolution as the source of common sound patterns. To take just one example, consider the common distribution of contrastive voicing summarized in (1). Lithuanian, an Indo-European language, allows voicing contrasts in obstruents before vowels and sonorants, but neutralizes these contrasts elsewhere. The same sound pattern has evolved independently within the Slavic, Germanic, and Italic subgroups of Indo-European. Within Italic, this pattern has evolved in Catalan, but not in French. Within West Germanic, the pattern has evolved in German, but not in English.[4] In sum, findings in historical linguistics present a wealth of evidence for parallel evolution in the world of sounds. Similar instances of phonetically based sound change occur in language after language. These sound changes are both the locus of phonetic explanation and the source of synchronic regularities in Evolutionary Phonology. It is to these sound changes that we now turn.

4.4 Explanations for patterns of laryngeal feature distribution

The general hypothesis of Evolutionary Phonology, and the one argued for throughout this book, is that parallel evolution is associated with phonetically based sound changes which recur with more than chance frequency due to inherent features of the human perceptual and articulatory system. The formal model of sound change proposed in 2.2 predicts that any sound change with sources in CHANGE, CHANCE, or CHOICE will give rise to sound patterns that are more frequent than those which do not have their sources in natural sound change. Common sound patterns will typically reflect common instances of sound change. In this section, the common patterns of laryngeal feature distribution in (1)–(3) are associated with common instances of sound change. The overarching generalization is that positions of contrast for a particular feature are those in which neutralizing sound change is unattested, while positions of neutralization are precisely those where phonetically motivated sound change is common.

4.4.1 Release features

Let us focus on the most significant generalizations which have emerged from the cross-linguistic study of laryngeal feature distribution, many of

[4] In fact, English dialects with word-final devoicing are reported. One case in Appalachian American English is discussed in 10.2.

them originally due to Steriade (1999a). One important generalization is that phonetic features timed with release have distributional patterns which are distinct from those timed with the onset of constriction or closure. A related generalization is that release features tend to be neutralized before obstruents and word-finally, while closure features tend to be neutralized after consonants and word-initially. In addition, there appears to be a significant tendency to devoice obstruents in word-final position, even in languages where voicing is primarily cued by segment-internal voicing or duration, as opposed to differences in voice onset time.

Why are release features like post-aspiration and ejection neutralized before obstruents and word-finally? Recall the discussion of variability in articulation in 2.2. There it was observed that stop–release is not distinctive in any attested spoken language. In some languages, like English, the release of word-final stops is optional. In other languages, like Marshallese, there is a strong tendency for final stops to be unreleased. In still other languages, like German, there is a strong tendency for final stops to be released. While a given language, dialect, or speech style may show a particular tendency for release or non-release of word-final stops, this phonetic feature is never contrastive. In fact, when careful speech is elicited, one often finds that non-released stops are released. In general, hyperarticulated speech may transform unreleased stops into released stops. In 2.5 I suggest that release as a distinctive phonological feature would be particularly nonaptive given the frequency of pre-vocalic contexts. Whatever the explanation, however, the fact remains that release is a variable feature of pronunciation for some sounds in nearly all well-described languages.

Now, consider how variability in release might give rise to the observed patterns of neutralization. There are many languages like Klamath, where distinct laryngeal series of stops are distinguished primarily in terms of release features. In Klamath, with plain voiceless, voiceless aspirated, and voiceless ejectives, voice onset time and burst quality appear to be the primary phonetic cues for the laryngeal contrast: plain stops differ from aspirated stops in VOT values, while ejectives differ from the other two series in possessing a glottal release which follows the oral release. Ejectives also carry longer VOTs than plain stops, and ejectives will typically differ from the aspirated stops in showing no formant structure following the moment of oral release. What happens to the three-way laryngeal contrast for oral stops when a word-final or pre-obstruent stop is unreleased? Without audible release, the primary phonetic cues for the three-way contrast are no longer perceptible, resulting in high probabilities of neutralizing sound change.

In this case, the phonetic source of sound change is two-fold involving CHOICE and CHANGE. First, there is the fact that, for all languages, the continuum of careful to casual speech allows for variation in the (audible) release versus non-release of consonants involving oral closure. If the frequency of unreleased variants is higher than that of released variants, these forms can become new norms of pronunciation – a simple and common case of CHOICE. For many segment types, like [m], release versus non-release may not result in any general increased instances of misperception. However, where laryngeal contrasts like those described for Klamath are involved, the absence of release will result in reduction of primary phonetic cues for laryngeal contrasts, with a greater likelihood of the unreleased stops being perceived by language learners as stops lacking aspiration or ejection. Note that the speaker may still be carrying out the same laryngeal timing sequence for the production of unreleased aspirates and ejectives; however, the absence of release will make these articulatory movements less perceptually salient, or even inaudible.

By expressing the relationship between non-release and neutralization in terms of sound change, a restricted phonetic typology is defined.[5] First, there will be languages which maintain a surface contrast between, e.g., plain obstruents and obstruents contrasting in laryngeal release features in final and pre-obstruent position. In these languages, by definition, stops will be audibly released. Languages of this type include Lushootseed (Urbanczyk 1995, 1996) and Bella Coola (Nater 1984), where ejectives and plain obstruents are contrastive in all positions, and there is audible release. Second, there will be languages in which neutralization of laryngeal release features occurs precisely in positions where obstruents are not released. A language of this type is the dialect of Bengali described by Kenstowicz (1994: 193), where aspiration and breathy voiced release are neutralized word-finally, and in pre-obstruent position, but obstruent voicing is maintained. A third type of language will reflect a *superficial* development from the Bengali stage to a subsequent one: neutralization patterns will reflect earlier non-release, but obstruents will be phonetically released. Klamath, as described by Barker (1963, 1964) reflects this language type. In this last case, the intrinsic variability of consonant release plays a role in rendering a once transparent relationship between phonological patterns and phonetic source translucent.[6]

[5] This typology may have practical applications. For example, in efforts to reconstruct the phonetics of Coahuilteco for the purposes of language revitalization, this typology has been useful. Ejectives clearly contrast with plain stops, but should they be produced as ejectives in pre-consonantal and final position or not? Troike (1996: 651) has discovered at least one example where an expected sequence of ejectives *p't'* is written as *pt'*, suggesting that Coahuilteco obstruents are not released in pre-consonantal position.

[6] This sort of translucency is problematic for Steriade's (1999a) account in which parallel phonetic and phonological phenomena are accounted for by the same constraints.

But what of the many other cases where neutralization in VC_1C_2V is to the laryngeal features of C_2? What phonetic fact explains the common pattern of regressive voice assimilation in obstruent clusters? As demonstrated by Raphael (1981) and Slis (1986) for voicing, there is a general perceptual preference for the cues present in stop bursts and C–V transitions to take precedence over those in the V–C transition, all else being equal. Viewed in this light, regressive voice assimilation involves a classic case of CHANGE: a sequence like [apda] is misperceived as [abda], resulting in regressive voice asssimilation. The same explanation can be given for assimilation in longer obstruent clusters, like the pattern found in Russian, where all obstruents take on the voicing feature of the last obstruent in the cluster.[7]

Finally, notice that this released-based account, originally due to Steriade (1999a), makes two predictions concerning voicing contrasts in stops versus fricatives, assuming that fricative voicing is typically cued by segment-internal noise (or duration) as opposed to release features. First, there are predicted to be languages in which stops undergo laryngeal neutralization due to non-release, but fricatives do not. This pattern is found in Turkish, where the voicing contrast for stops and affricates is neutralized word-finally and in pre-consonantal position, but the voicing contrast for fricatives is maintained in the same contexts. Second, across-the-board laryngeal neutralization of stops and fricatives under non-release is unexpected, unless laryngeal features of fricatives are specifically associated with release, an apparent cross-linguistic rarity.[8] This second prediction appears to be in conflict with the many languages which show consistent word-final devoicing of both stops and fricatives. In 4.4.4 I suggest an alternative pathway to final devoicing which predicts final devoicing of both stops and fricatives.

4.4.2 Closure features

If the absence of release can explain the most general features of laryngeal release feature distribution in (1), is there a mirror-image explanation for

[7] Work with chinchillas and quails shows evidence of categorical perception for voicing contrasts in oral stops (Kuhl and Miller 1978; Kluender, Diehl, and Killeen 1987). If their categories are based on similar perceptual features, chinchillas and quails should show the same tendencies in misperception, mistaking [apda] for [abda], and mistaking [abta] for [apta]. As far as I know, this prediction has not been tested.

[8] The segment types involved would be post-aspirated, ejective, or post-glottalized fricatives. Burmese has post-aspirated fricatives; ejective fricatives are found in Hausa and Tlingit; and post-glottalized fricatives are reported for Amharic and Yapese (Ladefoged and Maddieson 1996: 178–79; Demolin 2000; Maddieson 1998). In Tlingit, where consonants are typically audibly released in all positions, ejective fricatives occur in preconsonantal and final position (Story and Naish 1973; Maddieson et al. 2001).

the distributional patterns of the closure features of pre-glottalization and pre-aspiration summarized in (2) and (3)? Before answering this question, it is important to recognize that these two cases have significant differences which cannot be ignored. First, though there are many languages where a contrast between plain and pre-aspirated obstruents is absent in word-initial position, there are few languages in which phonological alternations provide evidence of neutralization in precisely this position. Since, within Evolutionary Phonology, regular phonological alternations are often the fossilized reflexes of regular sound change, this gap is puzzling, and suggests that the absence of pre-aspirates in word-initial position may be partly independent of neutralizing sound change. On the other hand, similar alternations in unrelated Yurok and Yokuts suggest that the restriction of pre-glottalized sonorants to post-vocalic position may, at least in some languages, be the direct result of neutralizing sound change. Given these differences, this subsection will limit itself to potential sound changes resulting in common distributional patterns of pre-glottalization in (2). In 4.4.3 an additional factor is suggested in the cross-linguistic distribution of pre-aspirates, one which is independent of laryngeal neutralization.

If the primary cue for sonorant laryngealization in some languages is creak on a preceding vowel, or a glottal stop preceding sonorant modal voicing, then it is not surprising that in contexts where a preceding vowel is absent, neutralization occurs. Unlike the account of release features, there is no reference to variation in this account. In a language like Yurok (Robins 1958: 9), with a contrast between /w/ and /w'/, where /w'/ is phonetically realized as a glide with preceding creak or glottal closure, utterance initial [ʔw] can be easily misheard by the listener as [w]. In this context, primary phonetic cues of creakiness on a preceding vowel or the post-vocalic silent interval of the glottal stop are absent. Over time, we expect that word-initial glottalized sonorants in languages with consistent sonorant pre-glottalization will tend to neutralize to plain sonorants, based on the perception of these segments in phrase-initial and post-consonantal positions.[9]

Timing of laryngeal articulations relative to oral constriction is often reversed for obstruents and sonorants (Sapir 1938, Kingston 1985), with laryngeal events typically timed to peak at release for obstruents, but at onset of oral closure in sonorants. Along with these differences in timing,

[9] It would be of great value to study the frequency of single-word utterances or single-word phrases in child-directed speech. If more content words occur either phrase-initially or phrase-finally in child-directed speech than in non-child-directed speech, a child may be more likely to generalize from phrase-final to word-final context, or from phrase-initial to word-initial context on the basis of raw phonetic token frequency effects.

we find significant differences in distributional patterns. Neutralization of obstruent release features is determined by the phonetic context immediately following the obstruent, while neutralization of sonorant onset features is determined by the phonetic context immediately preceding the sonorant. In the case of obstruent release features, the overarching generalizations can be explained by the presence versus absence of consonant release. For pre-glottalized sonorants, seemingly significant cross-linguistic generalizations can be explained in terms of the presence versus absence of a preceding phonetic context facilitating the perception of creak or a silent glottal closure. In both cases, common sound changes are suggested which lead to common sound patterns: in the first case, the absence of release leads to neutralizing sound change for non-released stops; in the second case, regular sound change takes pre-glottalized sonorants to plain sonorants in phrase- or word-initial position.

4.4.3 The origins of obstruent pre-aspiration

Though pre-glottalization of sonorants and pre-aspiration of obstruents may both be classified as phonetic closure features, significant differences set them apart. Despite distributional constraints, there is little evidence from phonological alternations or the historical record suggesting neutralization of obstruent pre-aspiration in word-initial or post-consonantal position. In fact, a contrast between post-aspirated and unaspirated stops is found initially, in languages like Icelandic, Gaelic, Nukuoro, and West Futuna, suggesting that initial position is not a position of neutralization for the phonological contrast, but one where the contrast has a *distinct phonetic realization*. In all of these languages, pre-aspirates are realized as post-aspirates word-initially.

Another significant difference between pre-aspirates and post-aspirates involves duration. While languages with allophonic pre- and post-glottalized sonorants provide little evidence of consistent durational difference between these two segment types, pre-aspiration differs significantly from post-aspiration in terms of duration. Thráinsson (1978) notes for Icelandic that "pre-aspiration typically has a normal segment length in Icelandic, whereas postaspiration is much shorter . . . This suggests that pre-aspiration is not simply the inverse of postaspiration, as its name and some phonetic descriptions might lead us to believe."[10]

Both the distribution of pre-aspirates and their bisegmental durations in some languages suggest potential historical origins in geminates or

[10] The length associated with pre-aspiration in Icelandic is also found in Skye Gaelic, but not in Lewis Gaelic where pre-aspirates are as short as other stops (Ladefoged and Maddieson 1996: 72).

consonant clusters. Geminates and consonant clusters in many languages are absent word-initially, and word-finally, but present intervocalically (see chapters 5 and 7). Consonant clusters and geminates typically have longer durations than single segments, in the same way that pre-aspirated segments in languages like Icelandic are longer than their post-aspirated counterparts. It is possible, then, that some of the synchronic distributional constraints on pre-aspirates may reflect earlier distributional constraints on geminates or consonant clusters. An investigation of the history of obstruent pre-aspiration in a variety of genetically unrelated languages yields some support for this hypothesis (Blevins and Garrett 1993): in all cases where evidence is available, and where language contact is not involved, pre-aspirates seem to derive from earlier geminates or clusters. For example, in Lule Sami, pre-aspirates reflect medial geminates in other dialects, while in Cree, where pre-aspirates are found only after vowels, they are the result of a *CC > hC sound change (Bloomfield 1946: 88–90).[11]

4.4.4 Final devoicing

Some laryngeal features are cued by phonetic features internal to a segment. One case of this kind is the obstruent voicing contrast: in some languages, the primary cue for voiced (versus voiceless) stops is closure voicing and/or closure duration. While most languages combine segment-internal voicing and duration cues with differences in VOT, preceding vowel length, F_0 and F_1 values on adjacent vowels, and burst duration and amplitude, there are some languages like French, Catalan, and Thai where primary phonetic cues for the voicing contrast are closure voicing and closure duration. Since, in at least some languages, the cues for voicing are internal to the segment, and not aligned with stop release, presence versus absence of release should not result in neutralization of the voicing contrast. Nevertheless, we find that in languages like Catalan and Thai there is no voicing contrast for obstruents in word-final position. Assuming that the phonetic realization of voicing in these languages has been constant for some time, final devoicing cannot be attributed to the absence of release.

This finding should not be surprising since a purely release-based approach to final neutralization of voicing contrasts also makes the wrong predictions with respect to stops and fricatives. Under a purely

[11] In Ojibwe, clusters whose first member continues Proto-Algonquian *h, *x, *ʔ, or *θ are realized in some dialects as "fortis" or long stops *pp, kk, cc, tt* and in others as pre-aspirated stops.

release-based approach, word-final fricative devoicing is unexpected, since fricative voicing is cued by presence versus absence of noise during the fricative noise portion of the segment. And yet, many languages, including German and Russian, show devoicing of stops and fricatives word-finally. If release cues are not involved, what other phonetic factors might play a role in the evolution of word-final obstruent devoicing?

In Smith's (1997) detailed phonetic study of the devoicing of /z/ in American English, devoicing is found to be most common in two different contexts: first, where the fricative is followed by another voiceless consonant; and second, at the ends of words and phrases, and in unstressed syllables. Smith (1997) identifies two distinct causes of devoicing. In the first case there is glottal abduction, and transglottal airflow is insufficient for vocal-fold vibration. Glottal abduction occurs in anticipation of a glottal opening in a following voiceless sound, and also prepausally. A reduced glottal abduction gesture may also occur in contexts of reduction. These findings are consistent with the common devoicing of final unstressed vowels in many languages (see 8.2.1), as well as the offglides to voicelessness which, for example, are possible after all Klamath word-final segments (Blevins 1993a). A second cause of devoicing identified by Smith is when the transglottal pressure differential is too small to allow voicing. This study suggests then that there are quantifiable articulatory and aerodynamic factors which may lead to obstruent devoicing preceding other voiceless obstruents, and obstruent devoicing phrase-finally. In the current model of sound change, these articulatory and aerodynamic factors, in particular those which result in word- and phrase-final devoicing, shape the set of phonetic variants from which learners must choose to model their own sound system. Smith's (1997) study, then, suggests a phonetic source of devoiced final obstruents (and sonorants) for sound change with sources in CHOICE which is independent of release features.

An additional potential phonetic source for cross-linguistic word-final obstruent devoicing is also independent of closure and release cues and non-assimilatory in nature.[12] In many languages, a phrase-final syllable is longer in duration than a segmentally identical phrase-medial syllable (Klatt 1975; Wightman et al. 1992; Fougeron and Keating 1997). Phrase-final or pre-pausal lengthening can often result in segments which are two to three times longer than their non-lengthened counterparts. In some languages, like Modern Hebrew (Berkovits 1993), final lengthening has the greatest effect on final plosives and fricatives. In addition, as noted first by Catford (1977), there is a near universal association between

[12] I thank John Ohala for his comments on early versions of this hypothesis.

consonant duration and voicing: in obstruents, voiced obstruents are shorter than their voiceless counterparts. Together, these two observations suggest that phrase-final lengthening is one phonetic source of word-final obstruent devoicing, and that perceptual and articulatory factors may both be involved.

If phrase-final lengthening results in lengthening of closure duration, obstruent voicing can be inhibited.[13] The standard explanation for the association between length and voicelessness is aerodynamic: when the vocal folds are in the position for modal voicing, soon after obstruent closure, voicing ceases due to the supralaryngeal pressure resulting from the oral closure if no other strategies (e.g. relaxation of oral soft tissue, tongue root advancement, jaw lowering, etc.) are made use of to sustain vocal-fold vibration. In addition, longer stop duration can contribute to a percept of voicelessness, since voiceless stops are typically longer than their voiced counterparts, or have lower V-to-C durational ratios than their voiced counterparts (e.g Kohler 1979). A working hypothesis then is that due to common phrase-final lengthening, phrase-final consonants may be lengthened. As a result of this lengthening, two things may happen: voicing may be inhibited as a result of prolonged closure duration; or final lengthened voiced obstruents may come to have durations not unlike voiceless obstruents in non-final position, and be misperceived as voiceless. Either factor could result in a listener categorizing a word-final voiced obstruent as voiceless.

The proposed analysis has neither of the weaknesses of the purely release-based approach outlined above. In languages like French, Catalan, and Thai where primary phonetic cues for the voicing contrast are closure voicing and closure duration, final devoicing can evolve through phrase-final lengthening. In addition, such devoicing should affect both stops and fricatives, since there is no association between devoicing and absence of release. Another welcome result of separate phonetic accounts of general final devoicing and neutralization of release features is that it allows for loss of features like breathy voice under non-release, without neutralization of final voicing. This is precisely the pattern observed in some dialects of Bengali (Kenstowicz 1994: 193), where the word-final contrast between T^h, T, $D^ɦ$, D is neutralized to T versus D, with loss of release features, but no loss of the voicing contrast. Another prediction of a model in which final devoicing is an aerodynamic consequence of final lengthening is that phonetic devoicing will be most common in velar consonants, less common in coronal consonants, and less

[13] This is related to the findings of Klingenheben (1927), Jaeger (1978), and Ohala (1983b, 1994a) that geminates tend to be voiceless.

common still in labial consonants (Ohala 1983a). Where final devoicing has been captured in its earliest stages, there is evidence for this pattern. In Tonkawa, word-final *g* is devoiced to [k], but *b, d* are not (Hoijer 1933: 4). In Frisian, where final devoicing of *b, d, g* is of recent origin, Tiersma (1985: 30) reports early studies of the language of Grou by Eijkman (1907) where *b* and *d*, in contrast to *g*, are still voiced. Another implication of the final-lengthening account, also illustrated by Frisian, regards vowel-length effects. If phrase-final lengthening results in generally longer syllables, and if a language already has a long versus short vowel contrast in final syllables preceding voiced stops, then phrase-final lengthening may, in some languages, have a greater effect on consonants following long vowels than short vowels, due to upper limits on the length of sonorant portions of the syllable rime. In Sipma's (1913) grammar of Frisian, there are signs that devoicing has started to take place. Though his transcriptions are not entirely consistent, they suggest that devoicing took place first after long vowels, falling diphthongs, and liquids, and only later after short vowels or rising diphthongs (Tiersma 1985: 30).

At the same time, the suggestion that phrase-final lengthening may play a role in final devoicing is not meant to rule out other phonetically based sound changes which may result in convergent sound patterns. If final lengthening and final non-release both play a role in neutralization of voicing contrasts, this neutralization is expected to be more common than final neutralization of aspiration or ejection, which occurs only under non-release. This explanation is also not meant to rule out other potential factors, such as those noted by Smith (1997). Vocal-cord abduction in pre-pausal position is not uncommon. However, in languages where this occurs and appears to be phonologized (e.g. Klamath), both obstruents and sonorants are followed by audible voicelessness word-finally.[14]

4.4.5 Common cases of sound change

In (4) sound changes giving rise to some of the common patterns of laryngeal feature distribution in (1)–(3) are classified and summarized.

[14] Baudouin (1895/1972: 209–10) was perhaps the first linguist to explicitly note that sound changes like final devoicing not only occur in mature linguistic systems, but that they also independently arise in the course of language acquisition. Stampe (1969) refers to similar sound patterns in child-language development as "phonological processes," and suggests that they are part of universal strategies used in the course of language acquisition. However, see 9.1.4, where most aspects of sound patterns during early stages of language acquisition are argued to be due to maturational constraints on production. In child-language phonology, neutralization of voicing contrasts is found word-initially as well as word-finally, supporting this general view.

(4) Some sound changes resulting in recurrent patterns of laryngeal feature distribution

Sound change	Type	Phonetic basis
i. $T^h > T^{\urcorner}$, $T' > T^{\urcorner}$, $D > T^{\urcorner}$	CHOICE + CHANGE	i. variation provides released and unreleased tokens of stops, with unreleased tokens most common in certain positions (finally, pre-consonantally); ii. If a stop is unreleased, laryngeal features typically associated with release can be absent, or misperceived as being absent.
ii. ’R > R/ X__ (X not a vowel)	CHANGE	Sonorant pre-glottalization is cued by vowel shift from modal voicing to creak or glottal stop. When vowel is absent, pre-glottalization is commonly misperceived as being absent.
iii. [−son] > [−voiced] / __ //	CHOICE + CHANGE	i. General phrase-final lengthening results in lengthened final consonants; if these variants are taken as basic, sound change can result. ii. Lengthening may inhibit obstruent voicing directly, or lengthened tokens may be may interpreted as voiceless, since voiceless consonants are typically longer than voiced ones.
iv. $T_iT_i > {}^hT$, $T_iT_i > C^h$	CHOICE	Variation in timing of oral and laryngeal gestures can give rise to voiceless geminates produced as pre- or post-aspirated stops. Distribution of resulting aspirates will be identical to original distribution of geminates.

The sound changes proposed in (4i) involve a shift from released to unreleased consonants, and associated neutralizations of release features. The typical contexts for these changes are phrase-final position, word-final position, and pre-obstruent position; less commonly release is lost before other consonants. The changes in (4i) are unattested in pre-vocalic position within the word, since in this context consonants are released. Sound changes like those in (4i) are common because presence versus absence of release can be highly variable across time, speakers, and utterances. Final release may be common in hyperarticulated speech, but may be absent elsewhere.

In (4ii), pre-glottalized sonorants are misheard as plain voiced sonorants when a preceding vowel is absent. This sound change has been phonologized in languages like Yurok, giving rise to alternations, but the same sound change may also account for the limited distribution of glottalized sonorants in languages like Yokuts and Shuswap.

The final devoicing sound change in (4iii) is well documented cross-linguistically, and appears to have multiple sources. By relating this sound change to final lengthening, it is entirely independent of stop release. This is a welcome result since obstruent devoicing in many languages applies to both stops and fricatives, and occurs in languages where voicing is cued by segment-internal features like closure duration and closure voicing. In addition, the possibility of final-stop devoicing via non-release and final lengthening suggests that final-stop devoicing will be more widespread than other types of laryngeal neutralizations, since it has multiple sources. This appears to be the case.

In (4iv), the distribution of pre-aspirates is accounted for, in part, by the reanalysis of geminate obstruents as pre-aspirates. Under this account, distributional constraints on pre-aspiration may be directly inherited, and reflect earlier constraints on the distribution of geminates.

4.5 Exceptional patterns of laryngeal feature distribution

4.5.1 Final voicing

The phonetic-historical explanations proposed above for common patterns of laryngeal feature distribution are also meant to explain the absence or uncommon occurrence of other patterns. Certain patterns of laryngeal feature distribution will be unattested, or extremely rare, since common sound changes will not give rise to them, and other common sound changes will eliminate them. Above, final-obstruent devoicing is suggested as the convergence of at least three independently attested types of sound change: CHANGE based on the common misperception of unreleased consonants as plain voiceless consonants; CHANGE/CHOICE based on phrase-final laryngeal spreading gestures; and CHANGE/CHOICE based on final lengthening of obstruents which can result in voicelessness or percepts of voicelessness. Together, these three factors are claimed to account for the high frequency of word-final obstruent devoicing cross-linguistically. But these same factors will render other patterns, like final voicing, rare or infrequent.

Natural sound changes giving rise to obstruent voicing are of two basic types: assimilation to a neighboring voiced consonant; or gestural reduction in lenition contexts, with spontaneous voicing or a percept of voicing, as a potential consequence.[15] Since word-final VC# contexts do not provide a natural context for voice assimilation to a neighboring consonant, the only natural source of final voicing for VC# is lenition. However, cross-linguistic surveys of lenition show that voicing is common only in intervocalic contexts (LaVoie 2001: 31–32). In short, there is no single natural sound change which will give rise to sound patterns involving word-final voicing. At the same time, if such a pattern were to arise, either through rule telescoping, analogy, or by chance, the same factors which account for the widespread occurrence of final devoicing would play a role in speeding the decay of the final-voicing pattern. Unsurprisingly, then, there are very few cases of word-final voicing reported in the literature.

Three cases within Austronesian are reported by the same author, and are therefore somewhat suspect. Kähler (1946/1949, 1960), as reported by Robert Blust (personal communication, 2001), transcribes only final voiced stops in two dialects of Malay, though elsewhere (e.g. word-initially and medially) he records a voicing contrast. However, the consistency of Kähler's transcriptions across these three languages, and his mention that final stops are unreleased, suggest that his voiced stop symbols have been used to transcribe precisely the same neutralized segments found in Standard Malay, or languages more distantly related to Simalur. All of these languages have undergone neutralization of final **-b, *-d, *-g* to voiceless (unreleased) *-p, -t, -k*.

Breton (Ternes 1970) has essentially the same distribution of voicing as Lithuanian, with one complication. As in Lithuanian, voicing is contrastive before sonorants, but elsewhere contrasts are neutralized. The difference between Breton and Lithuanian is that in Lithuanian word-final obstruents are voiceless, while in Breton they are voiceless, except

[15] In this second case, voicing is often associated with other phonetic features of lenited segments, including shortening of closure duration, reduction of intraoral air pressure, or a shift from stop to continuant. See LaVoie (2001) for many examples.

when a vowel-initial word follows within the phrase, in which case they are voiced. Since, in Breton, word-final obstruents are always devoiced in phrase-final position, or when followed by a consonant, it would seem inappropriate to treat this as an instance of general word-final voicing. Rather, voicing of the word-final segment is an instance of intervocalic lenition at the phrasal level.[16]

Lezgian, a Nakh-Daghestanian language, has a limited set of alternations which suggest final-obstruent voicing through telescoping and rule inversion (Yu 2001). Lezgian has a four-way laryngeal contrast between ejectives, voiceless aspirated stops, voiced stops, and voiceless unaspirated stops. In certain monosyllabic nouns, a plain voiceless stop in pre-vocalic position alternates with a voiced stop in word-final position: *pab/pap-a* 'wife,' *pad/pat-ar* 'side,' *mez/mets-i* 'tongue,' etc. This alternation is not found in polysyllabic unsuffixed nouns, or in other lexical categories. Yu (2001) suggests that these synchronic alternations reflect a historical sequence of intervocalic pre-tonic gemination, where geminates were voiceless, followed by degemination, and rule inversion. Synchronic final voicing in Lezgian, then, appears to reflect historical medial devoicing.

What Breton, its hypothetical descendants, and Lezgian are meant to illustrate is that word-final voicing is not ruled out within Evolutionary Phonology. It is not ruled out as a general sound pattern, and it is not ruled out as the output of a limited set of phonological alternations. Rather, the common sound changes which make word-final devoicing common will make sound patterns limiting final obstruents to voiced ones uncommon. Since exceptionless patterns of word-final voicing will never be the direct transparent result of a phonetically motivated sound change, they are predicted to be less common than patterns of final devoicing. Their rarity follows not from any intrinsic property of synchronic grammars, but from contingent facts about the world.

4.5.2 Initial devoicing

Another rare and unexpected laryngeal feature pattern is word-initial obstruent devoicing. Word-final obstruent devoicing is attributed both to the absence of release and to phrase-final lengthening. Since word-initial pre-vocalic position is a context where obstruents are consistently released, devoicing with the same phonetic source is unexpected. However, phrase-initial strengthening is well documented (Fougeron and Keating 1997; Fougeron 1999). While the effects of phrase-final

[16] The French of Quimper has borrowed the word-final devoicing rule from Breton, but not the phrasal rule of intervocalic voicing.

lengthening on consonant length seem more extreme, it is possible that the few reported cases of word-initial devoicing have their origins in phrase-initial lengthening. These include Somali (Armstrong 1934), with devoicing of all voiced stops, and Pennsylvania German, with initial devoicing of /b/ to [p]. In these cases, initial lengthening may inhibit obstruent voicing, or simply give rise to the percept of voicelessness.

In Chamic (Thurgood 1999: 72–73), reflexes of Proto-Chamic word-initial breathy voiced stops have undergone neutralization to voiceless stops when the following syllable begins with a voiceless stop. Where the following syllable begins with a sonorant, breathy voiced stops are maintained initially. And where the following syllable begins with a voiced obstruent, there is maintenance of breathy voicing in Northern Roglai, loss of voicing in Chru and Phan Rang Cham, and variable maintenance of breathy voice in Jarai, and Western Cham. In reflexes of Proto-Chamic monosyllables, voicing is maintained word-initially. Within Chamic, the disyllabic domain is divided into a pre-syllable and main syllable. The pre-syllable is short and unstressed, while the main syllable is longer and stressed. Initial devoicing is limited to pre-syllables, and is conditioned by the laryngeal features of the onset of the main syllable. This then, is not a case of general word-initial devoicing, but a case of obstruent voice assimilation across a short unstressed vowel.

Another pattern which might be erroneously classified as word-initial devoicing is typical of those Pama-Nyungan languages which have only a single laryngeal series of obstruents, and prohibit word-final obstruents. In these languages, obstruents occur either word-initially or between sonorants (intervocalically, or after a sonorant consonant and before a vowel). Nearly all languages with these phonotactics have the same pattern of obstruent voicing: oral stops are voiceless word-initially, but tend to be voiced medially. This is the pattern found, for example, in Panyjima (Dench 1991: 130). This distribution of stop allophones is a consequence of simple intersonorant lenition.

4.6 Summary

In this chapter the most common patterns of laryngeal feature distribution in the world's languages have been attributed to common types of sound change. Certain patterns of laryngeal feature distribution reflect the fact that laryngeal features of obstruents are more perceptually salient in certain contexts than in others. In contexts in which these features are less salient, neutralizing sound changes may occur, and it is these sound changes which are reflected in the most common distributional patterns of laryngeal features. The same phonetic contexts of perceptual saliency define triggers in rules of laryngeal feature assimilation. Phrase-final lengthening as well as the association between phonation types and prosodic boundaries may also play a role in the common process of word-final devoicing.

At the same time, uncommon patterns of laryngeal feature distribution can also be explained in terms of sound change. Final voicing is rare not only because sound changes giving rise to final devoicing are common, but also because there is no single phonetically motivated sound change whose immediate output will give rise to this pattern. Rule inversion and rule telescoping may give rise to patterns of final obstruent voicing, suggesting that the rarity of such patterns does not follow from universal markedness constraints.

Within Evolutionary Phonology, the relationship demonstrated by Steriade (1999a) between positions of laryngeal feature neutralization and phonetic cues for laryngeal features are accounted for by positing phonetically based sound changes with sources in CHANGE, CHANCE, and CHOICE. These sound changes give rise to synchronic sound patterns with similar characteristics, but allow synchronic phonological systems to remain free of reference to phonetic features, and to diverge dramatically from phonetically natural sound patterns when rule inversion, rule telescoping, analogy, or language contact are involved.