

A theoretical synopsis of Evolutionary Phonology

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1. An overview of Evolutionary Phonology

1.1. *Explaining sound patterns*

Phonology is the study of sound patterns of the world's languages. In all spoken languages, we find sound patterns characterizing the composition of words and phrases. These patterns include overall properties of contrastive sound inventories (e.g. vowel inventories, consonant inventories, tone inventories), as well as patterns determining the distribution of sounds or contrastive features of sounds (stress, tone, length, voicing, place of articulation, etc.), and their variable realization in different contexts (alternations). A speaker's implicit knowledge of these patterns is often evident in their extension to novel items and in experiments probing phonological well-formedness. This implicit knowledge – its content, formalization, and representation, – is the central focus of modern theoretical phonology, including generative phonology and many of its derivatives (natural phonology, government phonology, dependency phonology, optimality theory).

However, just as important as speaker's implicit knowledge of sound patterns are explanations for the distribution of sound patterns across attested spoken languages. Some sound patterns, are extremely common, while others are rare. Some examples of recurrent sound patterns involving segment/feature inventories, distribution, and alternations are listed in (1). The sound patterns in (1i, iii, iv, v, viii) are exceptionless across the world's attested spoken languages, while those in (1ii, vi, vii, ix–xii) are recurrent and frequent. Exceptionless patterns like (1i) are sometimes regarded as 'linguistic universals' (1i), while common patterns like (1ii) are often viewed as 'universal tendencies'.

(1) Some recurrent sound patterns in the world's languages¹*Inventories*

- i. All spoken languages have consonants and vowels.
- ii. Most languages with only three vowels have the vowels /i, u, a/.
- iii. If a language has click consonants, it has other consonants also.
- iv. No language has more than five level tones.

Distribution

- v. In all languages with a voicing contrast, this contrast is found before vowels.
- vi. In many languages with a voicing contrast, this contrast is not found at the end of words.
- vii. In many languages, long vowels are stressed in preference to short vowels.
- viii. There are no languages where short vowels are consistently stressed in preference to long vowels.

Alternations

- ix. In many languages /k/ is pronounced as [tʃ] when followed by /i/.
- x. In many languages /n/ is pronounced as [m] when followed by /p/, /p^h/, or /b/.
- xi. In many languages voiced stops (/b/, /d/, /g/, etc.) are pronounced voiceless at the end of words.
- xii. In many languages, a high tone is lost when there is another high tone in the word.

Other sound patterns, like those in (2) are exceedingly rare, and might be considered impossible if not for the one or two languages described in sufficient detail. In some cases, the discovery of rare features has forced expansion of the notion of 'possible contrast' (2iii, iv) or 'possible sound pattern' (2vii) in very recent history, highlighting the fact that non-existence of particular sound patterns should not be interpreted as primary evidence of their impossibility.

¹ Some key references for these sound patters are: Maddieson (1984) for (1ii–iii); Yip (2002) for (1iv, xii); Steriade (1999), Blevins (2004a) for (1v, vi, xi); Hayes (1995) for (1vii, viii); Guion (1998) for (1ix); and Ohala (1990) for (1x).

(2) Rare sound patterns in the world's languages²

Inventories

- i. egressive, voiced, lateralized apico-alveolar/sub-laminal double-flap (Pirahã)
- ii. oral/semi-nasalized/nasalized vowel contrast (Palantla Chinantec)
- iii. pharyngeal vs. epiglottal fricative contrast (Burkikhan dialect of Agul)
- iv. contrastive labiodental nasals (Kukuya dialect of Teke)

Distribution

- v. word-initial CCCCCC and even CCCCCCCC clusters (Georgian)
- vi. word-initial geminate /h:/ (Taba)
- vii. all words begin with vowels (Eastern Arrernte)
- viii. lexical tone on mono- and di-syllables, stress elsewhere (Ket)

Alternations

- ix. rhotic vowel harmony (Yurok)
- x. {t, t^h, d} > s/_m (Ancient Greek)
- xi. Voiceless /t/, /k/ are pronounced as voiced word-finally (Somali)
- xii. Shift of M to L tone after voiced obstruents, sonorants, glottal stop, & implosives (Zina Kotoko)

In addition to these sorts of typological observations involving synchronic sound patterns, there is also a striking similarity between recurrent sound patterns and common instances of sound change. Pervasive parallels between common synchronic alternations and common instances of sound change have suggested to many, most notably the Neogrammarians, that recurrent synchronic sound patterns are a direct reflection of their diachronic origins, and, more specifically, that regular phonetically based sound change is the common source of recurrent

² Some key references for these sound patterns are: Everett (1982) for (2i); Merrifield and Edmonson (1999) for (2ii); Ladefoged and Maddieson (1996) for (2iii, iv); Vogt (1958), Hewitt (1995) for (2v); Hajek and Bowden (1999) for (2vi); Breen and Pensalfini (1999) for (2vii); Vajda (2004, 2005) for (2viii); Robins (1958) for (2ix); Garrett and Blevins (to appear) for (2x); Saeed (1999) for (2xi); Odden (2005) for (2xii).

sound patterns. Evolutionary Phonology (Blevins 2004a) investigates this hypothesis and explores its consequences for phonological theory and models of sound change. In this brief synopsis, I summarize results of recent research in Evolutionary Phonology, and highlight implications of these results for theoretical approaches. To set the context for this synopsis, the following section briefly reviews the central tenets of this approach, and ways in which it differs from, and builds on, earlier traditions.

Central to Evolutionary Phonology (Blevins 2004a) is the attempt to explain why certain sound patterns have the typological distributions they do. Why are certain sound patterns extremely common, while others are rare? What factors play a role in determining similar sound patterns across languages? And what is the ultimate explanation for the striking identity between recurrent context-dependent instances of sound change and recurrent alternation types across the world's languages?

Within Evolutionary Phonology (Blevins 2004a), the attempt to explain recurrent sound patterns like those in (1) gives equal consideration to all potential sources of similarity. As with similar biological characteristics, two languages may have similar sound patterns due to: (i) inheritance from a mother tongue; (ii) parallel evolution in the form of parallel phonetically motivated sound change; (iii) physical constraints on form & function, in particular, innate aspects of speech perception & production, and potential phonological universals; (iv) 'non-natural' or external factors (e.g. language contact, prescriptive norms, literacy, second-language learning); (v) or mere chance. These five general sources of similarity are listed in Table 1, with representative biological and linguistic examples of each category.

Shared genetic traits of biological organisms are comparable to shared inherited features of genetically related languages. For example, coda *r*-less dialects of British English and Australian English share the feature of *r*-lessness (and the occurrence of linking *r*) because the earliest English-speaking inhabitants of Australia were speakers of a dialect of English with this sound pattern, passed along to subsequent generations (Schneider et al. 2004).

However, the same is not true of final obstruent devoicing in Indo-European languages (e.g. Catalán, Russian, German), Turkic (e.g. Turkish), or Cushitic (e.g. Afar). Final devoicing is not a sound pattern

Table 1. *Sources of Similarity*

Source of Similarity	Biological	Linguistic
a. Direct genetic inheritance	Shared genetic traits of identical twins, e.g. eye color	Shared inherited features of British and Australian English, e.g. <i>r</i> -loss
b. Adaptation by natural selection	Independent development of toepads in <i>Iguanidae</i> , <i>Scincidae</i> , and <i>Gekkonidae</i>	Independent development of final obstruent devoicing in Indo-European, Turkic, Cushitic, etc.
c. Physical constraints on form & function	Patterns of spots and stripes on cats and seashells, as determined by chemistry/physics	Universal gross category boundaries for consonant types, as determined by categorical perception
d. “Non-natural” or external factors	Grafting, hybridization, genetic modification	Language contact/diffusion, prescriptive norms, literacy and second language learning
e. Chance	Arctic hares and albino rabbits have white coats, but ...	Japanese and Gilbertese only allow nasal Cs word-finally, but ...

reconstructed for Proto-Indo-European, Proto-Turkic or Proto-Cushitic. Rather, final devoicing as sound change has occurred many times independently in linguistic history, resulting in similar patterns across unrelated languages. Multiple factors contribute to instances of recurrent sound change, the most important being variable articulation, universal biases in perception, and language-specific perceptual biases. These multiple factors act as filters, determining differential rates of successful sound pattern ‘replication’ or transmission across successive generations. As sound patterns are transmitted across generations, there are parallel instances of final devoicing, as articulatory and perceptual constraints combine to limit successful replication of voiced obstruents in final position. This sort of parallel evolution is widely documented in the biological literature. Ancestor lizards of the *Iguanidae*, *Scincidae*, and *Gekkonidae* families did not have toepads, but toepads evolved independently in these three branches when lizards moved to arboreal habitats, where toepads provided a selective advantage in terms of clinging ability (Larson and Losos 1996). As with the linguistic example of final devoicing, multiple factors are involved, including genetic potential for toepad evolution, and environmental biases where toepads enhance overall fitness.

An additional source of similar traits in the biological world are physical constraints on form and function. Patterns of spots and stripes on cats and seashells are curiously similar, not because they have been inherited from a common ancestor, or due to parallel evolution, but because they result from similar biochemical processes (Stewart 1998). In the same way, human adults (Liberman et al. 1967), human infants (Eimas et al. 1971), macaques (Kuhl and Padden 1982), chinchillas (Kuhl and Miller 1975) and parakeets (Dent et al. 1997), all show evidence of categorical perception (Aslin and Pisoni 1980): change along, for example, the acoustic voice-onset-time continuum is perceived, not gradually, but as instances of discrete categories. This physical constraint is arguably an innate feature of the human perceptual system, and possibly of non-human perceptual systems as well, and plays a central role in defining phonologically contrastive category boundaries across languages.³ Since categorical perception is present at birth, it clearly is not a result of direct inheritance from a mother tongue or parallel evolution. It is a physical constraint whose effects should be apparent in all spoken languages. Within this model, any innate linguistic knowledge would fall into the same category.

In addition to natural or system-internal sources of similarity, unnatural or external influences may also play a role. Ancient tree grafts have been replaced by modern plant hybridization and genetic modification. In some cases (e.g. certain plant hybrids), these external influences mimic natural processes, while in other cases (e.g. insertion of fish genes into plants), they do not. The same is true in sound patterns, where language contact, prescriptive norms, literacy, and transfer effects in second language learning can result in unremarkable patterns or remarkable ones, which are rare or unattested outside of these contexts. In the unremarkable class is, for example, the pattern of final devoicing in the Tosk dialect of Albanian, which is neither inherited, nor naturally evolved, but a consequence of linguistic contact. In the more remarkable class are

³ Though see: Pisoni and Tash (1974), Andruski et al. (1994), and Miller (1994) on the graded internal-structure of phonetic categories; Damper and Harnard (2000) on categorical perception as a potential emergent property of powerful general learning systems; and Pinker and Jackendoff (2005) for significant differences between human and non-human speech perception.

click sounds in the Bantu languages Zulu and Xhosa, borrowed from neighboring Khoisan languages. Natural phonetically motivated sound changes taking non-clicks to clicks are unattested in historical phonologies suggesting that all languages with clicks have either inherited these, or acquired them via contact.

Finally, though characteristics may appear similar and may be of high frequency, we cannot assume that their occurrence is significant. It is always possible that similarities constitute chance events, and that similarity is only superficial. In the biological world, we can compare the white coat of an albino rabbit (of any species), determined by a naturally occurring genetic mutation associated with lack of skin pigmentation, with the white coat of the arctic hare (*Lepus Timidus*), whose coat varies with the season except in its northernmost extent, and is white due to presence of pigmentation. Despite superficial similarities, the source of whiteness in the two cases is completely different. The same is often true of sound patterns. Consider a strikingly similar phonotactic constraint in two unrelated and geographically distant languages. Japanese allows only nasal codas in word-final position, and the same is true for Gilbertese, a Micronesian language. While these patterns are superficially similar, they reflect unnatural and natural developments respectively. Old Japanese lacked closed syllables altogether, with nasal codas arising through contact with Chinese. Gilbertese, on the other hand, has nasal codas as a consequence of regular sound change.⁴

This general approach to explanation in Evolutionary Phonology is rooted in the view of language as a as a complex adaptive system whose evolution can be usefully compared to the evolution of biological organisms. A similar view is shared by other more general approaches to language structure (e.g. Wildgen 1990; Keller 1994; Cooper 1999; Haspelmath 1999; Kirby 1999; Croft 2000; and Bod et al. 2003), and by many whose primary focus is sound patterns (e.g. Lindblom et al. 1984; Lindblom 1992; Ohala 1989, 1993; Steels 1997, 2000; Blevins and Garrett

⁴ See Blevins (2004a: 47–52) for references and further discussion. These sorts of chance events are sometimes referred to as instances of convergent evolution in the biological literature: traits are superficially similar but have arisen through distinct developmental pathways from different ancestral conditions.

1998, 2004; Bybee 1998, 2001; de Boer 1999, 2001; Harrison et al. 2002; Kochetov 2002; Pierrehumbert 2003; Mielke 2004; Ritt 2004; Wedel 2004a; Boersma 2005; Oudeyer 2005). Research in this second group suggests multiple ways in which sound patterns are emergent probabilistic properties, resulting from the repeated interaction of innate perceptual and articulatory biases, self-organizing properties of sound systems, and aspects of language use within a population.

An important premise, related to this general approach, distinguishes Evolutionary Phonology from Generative Phonology (Chomsky and Halle 1968; Kenstowicz and Kisseberth 1979; Kenstowicz 1994; to appear), and Optimality Theory (Prince and Smolensky 1993; Kager 1999; McCarthy 2002). The premise is that principled *extra-phonological* explanations for sound patterns have priority over competing *phonological* explanations unless independent evidence demonstrates that a purely phonological account is warranted.⁵ In terms of the sources of similarities in Table 1, this means that similar sound patterns which are directly inherited from a mother tongue (a), the consequence of recurrent natural phonetically motivated sound change (b), the result of language contact, prescriptive norms, or literacy (d), or due to chance (e), should not be attributed to innate linguistic phonological knowledge (c). This central premise has already yielded impressive results, with many recurrent sound patterns reclassified as instances of parallel evolution under phonetic

⁵ It is unclear whether this premise is central to the phonetically-based optimality approaches of, e.g. Boersma (2003, 2005) or Hayes and Steriade (2004). In the latter, markedness constraints “need not be universal or innate” but are constraints “whose violations are evaluated solely on surface forms.” In both models, phonological knowledge is formulated in terms of extensive inventories of violable constraints, some of which encode what are otherwise thought of as gradient phonetic properties. If these constraints are claimed to arise or emerge, in part, from detailed phonetic knowledge of the lexicon (cf. Ernestus and Baayen 2003), then the question comes down to motivating these phonetic constraint inventories over alternatives (e.g. phonetic exemplar-based lexicons, or positive probabilistic constraints based on generalizations over the lexicon). I am unaware of evidence demonstrating that grammatical constraints of the sort proposed in these models encoding perceptual similarity, perceptual salience, or articulatory ease are warranted. Phonetic explanations in these approaches and that advocated here may, in some cases, be similar, but the insistence that these phonetic explanations are encoded as defeasible markedness constraints within Optimality grammars is an assumption which, from the evolutionary perspective, appears undermotivated.

variation and selection, and others analysed as chance occurrences with revealing unnatural histories (Blevins & Garrett 1998; Kochetov 2002; Blevins 2004b, 2004c; Blevins & Garrett 2004; Gessner & Hansson 2004; Hansson 2004; Mielke 2004; Wedel 2004a, 2004b; Yu 2004; Blevins 2005a; Kochetov and So 2005; Odden 2005; Shih 2005; Vaux and Samuels 2005; Blevins 2006, to appear a, to appear b; Iverson and Salmons to appear; Myers and Hansen to appear). Section 2 illustrates this premise as it applies to the typology of final obstruent devoicing, emphasizing the predictive value of the approach. Section 3 highlights the testable nature of hypotheses and their explanatory nature.⁶ Before turning to these results, a general typology of sound change is presented in 1.2, with brief notes on differences between the present approach and some of its intellectual precursors in 1.3.

1.2. *Replication, variation and selection in grammar construction*

Language transmission is a form of cultural evolution. Each human being constructs a language-specific grammar anew from information gleaned from the environment in the form of utterances of surrounding speakers. Cultural evolution, like biological evolution, involves three interacting processes: a source of variation; a means of high-fidelity information preservation between generations of variants; and one or more selective mechanisms serving as feedback loops between specific variants and ‘success’ (Steels 1997).

In the phonetic realm of human spoken languages, variation is an intrinsic feature of speech. Variation occurs across speakers, due to speaker-specific anatomical differences, and within the speech of a given speaker, due to phonetic transforms of speech dependent (at least) on: rate of speech; degree of physical effort involved; and the humanly physical

⁶ Earlier versions of the final devoicing study were presented in 2005 at the Max-Planck Institute for Evolutionary Anthropology, The Linguistic Society of America Annual Meeting, and the 13th Manchester Phonology Meeting. Assessments of sound change frequency are drawn from a database of regular sound change, currently under construction at the Max Planck Institute for Evolutionary Anthropology (Blevins, Kamholz & Bibiko, in preparation).

impossibility of making exactly the same sound twice. What is important to note, however, is that this type of variation is highly restricted: for example there are no known processes whereby a shortened, lengthened, reduced, or augmented [k] in /aka/ is pronounced as [m], since the articulation involved in producing a [k] (tongue back closure at velum, vocal fold position, etc.), when strengthened or weakened, lengthened or shortened, will not give rise to labial closure with simultaneous lowering of the velum. In other words, though phonetic variability for given phonemes, syllables and words is great, it is also locally limited by articulatory transforms. These transforms are schematized in (3iii) for unstressed vowel reduction, and are the basis of many types of regular sound change, as argued by Ohala (1989), among others. Within Evolutionary Phonology, regular sound change with primary sources in this type of phonetic variation is referred to as CHOICE, and can depend on simple frequency changes of variants across generations, as well as differential weightings of variants based on social factors, like those discussed extensively by Labov (2001).

- (3) A general typology of sound change, S = speaker, L = listener
- i. CHANGE: The phonetic signal is misperceived by the listener due to: acoustic similarities between the utterance and the perceived utterance; and biases of human perceptual system.
S says [anpa] L hears [ampa]
 - ii. CHANCE: The phonetic signal is accurately perceived by the listener but is intrinsically phonologically ambiguous. The listener associates a phonological form with the utterance which differs from the phonological form in the speaker's grammar.
S says [ʔaʔ] for /aʔ/ L hears [ʔaʔ], thinks /ʔa/
 - iii. CHOICE: Multiple phonetic variants of a single phonological form are accurately perceived by the listener. The listener (a) acquires a proto-type or best exemplar which differs from that of the speaker; and/or (b) associates a phonological form with the set of variants which differs from the phonological form in the speaker's grammar.
S says [tuʔəlan], [tuʔ^olan], [tuʔlan] for /tuʔəlan/
L hears [tuʔlan], [tuʔ^olan], [tuʔəlan], and assumes /tuʔlan/

The means of high-fidelity information preservation between generations of variants is language acquisition. Although there may be great

phonetic variability in the pronunciation of every word of a language, humans are skilled language learners, and appear to have little problem storing aspects of such variation, making use of them in the construction of individual grammars, and making use of a multitude of probabilistic generalizations over stored lexemes (Saffran et al. 1996; Johnson 1997; Frisch et al. 2000; Pierrehumbert 2000, 2003). However, in the process of language acquisition, there are at least two clear types of 'selective' mechanisms which result in broad recurrent 'directions' of change for phonological systems. These two types of selective mechanisms define two additional sources of sound change within Evolutionary Phonology.

One primary selective mechanism consists in perceptual biases in the human auditory system. In the course of language transmission, some acoustic patterns are more likely to be misperceived than others, often in a particular direction. This phenomena, sometimes referred to as 'innocent misperception' was first recognized as a potential factor in regular sound change by Baudouin de Courtenay (1910/1972), and solidly supported by subsequent research in laboratory phonology, in particular by the work of Ohala (e.g. 1971, 1981, 1990). Sound change whose primary source is 'innocent' misperception is referred to here as CHANGE with a representative example provided in (3i). For regressive nasal-place assimilation, like other sound changes of this type, there is experimental evidence that humans are more likely to misperceive in the direction of change than in the opposite direction, and that they are more likely to perceive in the direction of change than in some alternative way.

Another selective mechanism involves the resolution of intrinsically ambiguous signals. The source of sound change in this type is often long-domain features whose precise segmental location is in question. If resolution of ambiguity was a chance affair, we would expect just as many instances of sound change giving rise to innovative sound patterns, as those resulting in pre-existing sound patterns. However, in this category, termed 'CHANCE' (3ii), and illustrated here by an instance of laryngeal metathesis, frequencies are highly skewed. For metathesis (Blevins & Garrett 1998, 2004; Hume 2004) and compensatory lengthening (Kavitskaya 2002) there seems to be a strong cross-linguistic tendency for the direction of change under this type of ambiguity to be 'structure-preserving', resulting in pre-existing sound patterns. For metathesis, more than 90% of AB > BA changes take place when BA occurs in the earlier

stage of the language. For compensatory lengthening, figures are similar, with approximately 90% of languages undergoing this sound change having pre-existing vowel length contrasts (de Chene and Anderson 1979; Kavitskaya 2002).⁷ Blevins (2004a: 154) suggests that the basis for this tendency is Structural Analogy, as stated in (3):

(3) Structural Analogy

In the course of language acquisition, the existence of a phonological contrast between A and B will result in more instances of sound change involving shifts of ambiguous elements to A or B than if no contrast between A and B existed.

The basic intuition behind this learning mechanism is that there is an ambient priming effect on incoming data that can apply at any structural level in the phonology.⁸ In (3ii), laryngealization extends across a whole syllable, making segmental localization unclear. Now imagine that the language at large has many unambiguous CV syllables, but very few closed CVC syllables, which have been segmented by the learner. Structural Analogy allows the lexical dominance of open vs. closed syllables to play a role in the categorization of the ambiguous string. In this case, the result would be a higher probability of a /ʔa/ parse than a /aʔ/ parse. Notice that this selective mechanism is a property of language as a self-organizing system, and of language-learning as an analogical process. It

⁷ De Chene and Anderson (1979) treated pre-existing vowel length contrasts as a pre-condition for compensatory lengthening, though Kavitskaya (2002) shows that there are exceptions. Here, again, a theory must explain the high probability of these sound changes as structure-preserving, not pre-existing structures as a necessary condition for the change in question.

⁸ A reader finds this principle unilluminating: "... sound change is often structure preserving because it is subject to the principle of Structural Analogy, which says in effect that sound change tends to be structure preserving." But the principle refers not to sound change, but to the categorization of *ambiguous* elements in the course of language acquisition. Ambiguity is not a feature of all sources of sound change in (3). In particular, sound changes with sources in misperception (CHANGE), are not expected to show robust structure-preserving effects, since ambiguity is typically not involved. Given a perceptual bias to hear the nasal in VNTV sequences as homorganic with a following stop, this bias results in *non-ambiguous* misperceptions of VNTV tokens as homorganic, and can result, for example, in the evolution of velar nasals in a language which formerly lacked them, as has occurred in the history of English.

is not a direct consequence of specific asymmetries in the human auditory or articulatory system and it is independent of ‘innocent misperception’. While agent-based simulations of this sort of structural analogy have only just begun (e.g. Wedel 2004a, 2004b), they provide evidence for language-specific structural priming in the course of phonological acquisition.

Though the schematization in (3) recognizes three primary sources of “imperfect” phonological learning or sound change resulting in phonological evolution, most instances of regular mechanical sound change in the Neogrammarian sense are likely amalgams of these three types.⁹ What the typology highlights is that many recurrent sound changes have a dominant source, and that sound change is productively viewed in evolutionary terms: phonetic variation across phonological types and tokens is the norm; such variation can be transmitted across generations; and there are external (e.g. perceptual) as well as internal (structural analogy, frequency) selective mechanisms which effect the “success” rates or fitness of different variants.

1.3. *Evolutionary Phonology in historical context*

Evolutionary Phonology builds on the 19th century Neogrammarian view of the phonetic basis of sound change, its regularity, and the ability of sound change and analogical change together to explain synchronic sound patterns without assumptions of innate phonological knowledge. It extends Greenberg’s (1965, 1978) early typological work suggesting that notions of phonological markedness be replaced by substantive constraints on sound change. And it integrates these views of the relationship between sound change and phonological typology with recent results in phonetic theory and modelling, including: the evolution of phonetic categories (e.g. Lindblom et al. 1984); constraints on phonetic variation (e.g. Lindblom 1990); and the probability of misperception (e.g. Ohala 1981). Finally, hypotheses concerning phonetic explanation in phonology are

⁹ Similar integrative approaches, e.g. Wang (1979) and Mielke (2004), do not distinguish these three basic mechanisms of change, modelling them as interactions of perception, production, and language use, in the course of language acquisition.

suggested by work in laboratory phonology, and testable by the same methods (for a recent example, see Myers and Hansen to appear).

At the same time, it is worth pointing out significant differences in assumption and method between Evolutionary Phonology and other traditions. Where the Neogrammarians assumed that most instances of regular sound change had their bases in gradual articulatory shifts, Evolutionary Phonology adopts the expanded typology in (3), which includes articulatory-based variation, misperception, and difficulties in percept localization.¹⁰ Where Neogrammarians held to the regularity hypothesis, Evolutionary Phonology admits exceptions to regular sound change and attempts to explain them (Blevins 2005a, to appear a). And where Neogrammarian methods included the identification of cognate sets and sound correspondences, followed by proposed sound changes (the comparative method), Evolutionary Phonology starts from methods in phonetic and phonological typology and description, and, with Neogrammarian sound changes in hand, proceeds to theories attempting to explain why certain similarities and differences in sound patterns occur where they do across the world's spoken languages.

Evolutionary Phonology also differs in many ways from the typological tradition of Greenberg and his students, in following new trends in 21st century typology (Bickel 2005). Within the Greenbergian tradition, typology was used as an alternative method to generative phonology in determining the limits of possible human phonological grammars and the form of universal grammar. However, it soon became clear that there were exceptions to many proposed universals, and that this approach had little to say of strong universal tendencies, or linguistic rarities. In response, a new goal of typology has been the development of theories that explain why linguistic diversity is the way it is (Nichols 1992, Bickel 2005). Under this approach, universal tendencies are combined with geographic (contact) and inherited tendencies (drift), to produce probabilistic theories of occurring sound patterns under probabilistic theories of sound change.

¹⁰ Concrete reference to articulatory variation as a source of change in Evolutionary Phonology include Blevins (2004a: 31–44, 140–47). Nevertheless, the framework is sometimes erroneously associated with Ohala's model of 'innocent misperception', to the exclusion of other sources of sound change. For further discussion, see Blevins (to appear c).

Finally, Evolutionary Phonology attempts to rectify two inadequacies of Generative Phonology and Optimality Theory. The first inadequacy is that neither has, as a primary goal, the attempt to explain robust similarities between sound patterns and types of sound change. The second weakness, alluded to already, is the form of explanation provided for recurrent sound patterns in these theories. Generative Phonology and Optimality Theory both claim to rule out certain phonological systems and allow others by proposing innate aspects of phonological knowledge. But this level of explanation is at once too weak and too strong. It is too weak, because it fails to account for the high frequency of certain sound patterns and the rarity of others. And it is too strong because it incorrectly rules out attested sound patterns, which diachronic approaches correctly allow.¹¹ These two goals – to explain similarities between sound patterns and sound change, and seek extra-phonological explanations for them – also clearly distinguish Evolutionary Phonology from traditional historical linguistics, and from earlier typological approaches.¹²

¹¹ Another inadequacy of both models is the near monolithic treatment of all patterns as worthy of phonological generalization. Natural and unnatural sound patterns are not distinguished, and accidental similarities are sometimes confused with systematic ones. At the same time, there is mounting psycholinguistic evidence that some phonological generalizations are productive, while others are not (e.g. Sanders 2003, Blevins 2004b), and that some are gradient, while others are categorical (e.g. Frisch et al. 2004). Such studies suggest that proposed aspects of synchronic architecture, from rule-cyclicity (Chomsky and Halle 1968), to constraints on rule application (e.g. Myers 1991), Optimality theoretic treatments of opacity (McCarthy 2003), and the general separation of phonetics and phonology (cf. Frisch et al. 2004) are undermotivated. Blumstein (2004), in a recent overview of the relationship between phonetic categories and lexical processes, concludes similarly: “Even though the results of this research suggest that acoustic-phonetic structure influences the lexical-semantic network, *they do not speak to the nature of the representations of lexical form itself* [emphasis mine, JB]. That is, lexical form could be represented in terms of phonetic segments . . . Alternatively, it is possible that lexical form is represented episodically, maintaining the fine details of acoustic-phonetic structure in the lexical representation itself . . .” For further discussion of underdetermination in synchronic grammars, see Chapter 9 of Blevins (2004a), and Blevins (to appear d).

¹² Ohala’s school of phonology has similar goals, with a complementary focus on simulating sound change in the laboratory. By showing that sound change after sound change has phonetic motivation, there is less and less for phonological theory to explain (Ohala 2005). Studies which stand out in this tradition for their typological breadth are Guion (1998) on velar palatalization and Kavitskaya (2002) on compensatory lengthening.

2. Towards a theory of final devoicing

2.1. *Defining final devoicing*

In the natural world, we find many cases of parallel evolution, where organisms not closely related to each other develop similar characteristics under similar conditions. An empirical question is whether there are similar instances of parallel evolution in the world's sound systems. In this section I argue that final obstruent devoicing is such a case. Final devoicing occurs in languages which are not closely related to each other, and devoicing occurs under similar conditions, namely in obstruents and word-finally.

I also make a stronger argument, namely that final-devoicing is an *emergent property* of sound systems, not an intrinsic one. Under the evolutionary emergent analysis, final devoicing (*contra*, e.g., Lombardi 1994, 1995, 2001; Kiparsky 2004) does not stem from any *innate phonological universal* which prohibits, inhibits or otherwise restricts phonologically voiced segments.¹³ On the contrary, languages with final voicing are not excluded as possible sound systems. Rather, their rarity is attributed to (i) the prevalence of natural phonetic occurrences giving rise to final devoicing processes; and (ii) the rarity of the combination of specific features necessary to give rise to a language with an exceptional final voicing pattern. This is an important point because any demonstrated instance of convergence could be trivially attributed to an innate phonological constraint enforcing a very specific type of selection for precisely the emergent pattern. I argue instead that the diachronic profile of final devoicing has properties which are predicted under the evolutionary emergentist account, but incompatible or unaccounted for within synchronic/innateness proposals.

In many languages with a contrast between voiced and voiceless consonants like /b d g/ and /p t k/, only the voiceless segments /p t k/ occur word-finally. I will refer to this general pattern as 'final obstruent

¹³ Suggested universal phonological constraints in Optimality Theory include *[voiced], *[+voiced, -son] (= VOICED OBSTRUENT PROHIBITION), and *VOICED-CODA. In *Natural Phonology* (e.g. Stampe 1973) it is suggested that the phonological process of word-final obstruent devoicing is universal, subject to inhibition if final voiced obstruents are encountered in the course of language acquisition.

devoicing’ or ‘final devoicing’, and will restrict discussion to languages where the contrast between voiced and voiceless stops is one of *true voicing*: prevoiced lenis plosives contrast with zero to short lag VOT plosives utterance initially and (where relevant) after another obstruent.¹⁴ As with many other sound patterns in the world’s languages, the sound pattern of final devoicing can exhibit itself in the form of active alternations or static distributional patterns.

Of interest to us in the current context is the fact that final-devoicing as a sound change has occurred multiple times in the history of the world’s languages in unrelated language families and in places where contact-induced change is unlikely. A sample of genetically unrelated languages with synchronic final obstruent devoicing is shown in Table 2, representing

Table 2. *Final-devoicing sound patterns in unrelated languages*

Language/Family	Alternations	Data Source
Afar/Cushitic	yes	Bliese (1981: 242, 215)
Chadic Arabic/Semitic	yes	Zeltner & Tourneux (1986: 15–16)
Russian/Indo-European	yes	Halle (1959)
Ingush/Nakh-Daghestanian	yes	Geurin (2001: 90–92)
Mosetén/Mosetenan	yes (rare)	Sakel (2002)
Turkish/Turkic	yes (stops only) ¹⁵	Johansson & Csató (1998)
Awara/Finisterre-Huon	no	Quigley (2003)
Basque	no	Saltarelli (1998)
Old Chinese/Sino-Tibetan	no	Sagart (1999: 25, 51)
Malay/Austronesian	no (levelled)	Moeliono & Grimes (1995: 451)
Fyem/Niger-Congo?	no	Nettle (1998)
Thai/Tai-Kadai	no	Smyth (2002: 5–6)

¹⁴ For an extensive investigation of the phonetic realization of laryngeal ‘voicing’ categories in a range of languages, see Jansen (2004). Standard German is often used as a textbook example of a language with final devoicing (Kenstowicz and Kisseberth 1979: 212; Wiese 1996: 200–209). However, the majority of German dialects have a primary contrast between unaspirated and aspirated voiceless stops (short- vs. long-lag VOT), with this contrast neutralized in final position (Iverson and Salmons 1995; Jessen 1998; Jessen and Ringen 2002). An exception is Rhineland German as described by Kohler (1979).

¹⁵ Though see Kallestinova (2004), where phonetic evidence suggests that (i) the basic contrast in Standard Turkish is between aspirated and unaspirated stops, and (ii) a small number of stems (6 monosyllables) end in orthographic voiced stops which, for some speakers, do not undergo final devoicing. In this case, spelling pronunciations may be involved.

11 distinct language families and one isolate. Where available, comparative evidence and internal reconstruction lead one to conclude that at an earlier stage, voicing contrasts were present word-finally, followed by the sound change shown in (4).

- (4) Recurrent sound change of final devoicing
 $[-\text{son}] > [-\text{voiced}]/_]_{\text{Word}}$

For the languages listed in Table 2, direct genetic inheritance of final devoicing as a sound pattern can be ruled out for Afar, Chadic Arabic, Russian, Ingush, Turkish, Old Chinese and Malay based on comparative evidence. This is because final-devoicing is not a feature of the proto-languages, which in all cases contained voicing contrasts in word-initial and word-final position. For Mosetenan and pre-Basque, final-devoicing is based on internal reconstruction. Since Basque is an isolate, and Mose-tenan includes only several dialects or languages, and since there is no apparent contact source in either case for final-devoicing, these cases are assumed to be independent ‘natural’ developments. While it is impossible to rule out contact-induced devoicing in many cases where geographic location and linguistic neighbours of a proto-language are unknown, the languages listed in Table 2 are those where the majority of evidence points towards internal independent developments.

The methodological procedure of sorting synchronic sound patterns by their historical origins is, in modern phonological research, unique to the evolutionary approach, and worthy of short comment. If the frequency of sound changes like (4) is claimed to underlie the high frequency of synchronic final-devoicing sound patterns, then distinguishing instances of genesis from inheritance, contact-induced change, or accidental likenesses, is important in assessing predictions of the model. Of interest is the number of ‘types’ of a sound pattern, where each type represents one instance of unique genesis, and actual tokens include sound patterns acquired by descent, contact, or accident. If, after paring down to individual types, only one or two independent occurrences of final devoicing sound change are found in the world’s attested spoken languages, it would be incorrect to call this sound change and its synchronic reflections frequent. On the other hand, if after such weeding, there are more than a dozen instances of this sound change, as appears to be the case, then the sound pattern is a recurrent one, whose high frequency begs for explanation.

Table 3. *Final-devoicing in some Indo-European languages*

Language/Subgroup	Same-Subgroup Devoicing?	Neighbour Devoicing?
Frisian/Germanic	yes	yes/Dutch
Dutch/Germanic	yes	yes/Germanic
Rhineland German/Germanic	yes	yes/Germanic
Catalán/Italic	yes	yes/Provençal
Picard/Italic	yes	yes/Walloon
Walloon/Italic	yes	yes/Germanic
Tosk/Albanian	no (dialect chain)	yes/S Slavic
Russian/Slavic	yes	yes/other Slavic
Polish/Slavic	yes	yes/other Slavic
Slovene/Slavic	yes	yes/other Slavic
Bulgarian/Slavic	yes	yes/other Slavic
Lithuanian/Baltic	yes	yes/Slavic
Dari(Afghan)/Indo-Iranian	yes	yes/Turkish
Zazaki/Indo-Iranian	yes	yes/Turkish
East. Armenian/Armenian	no (dialect chain)	yes/Turkish

These methodological procedures are important because it appears that any sound pattern can spread via contact (Thomason and Kaufman 1988). Whereas ‘descent with modification’ is the primary means of evolution in the biological world, with rare cases of spontaneous natural hybridization, in language change these roles are nearly reversed (Garrett 2005). Linguistic change via diffusion is common, and new linguistic forms can spread across populations with great speed, independent of their ‘fitness’. In the specific case of final devoicing, there is evidence both at the level of individuals and communities of spread via contact. First language speakers of Dutch, Russian, Polish, and a variety of other languages without a final voicing contrast for obstruents typically extend this sound pattern to their second languages (Yavas 1994, Broselow et al. 1998). Some linguistic areas are defined by neutralization of a voicing contrast, for example, the eastern Sudan (Schadeberg 1987: 219–224), and there are many Indo-European languages, like those listed in Table 3, where either a sister language or dialect with devoicing exists. For the languages in Table 3, devoicing could be either a shared local innovation, or the result of diffusion from a neighboring devoicing language, giving rise to a contiguous final-devoicing area.

At the same time, we can rule out final-devoicing at the subgroup level for each language in Table 3, since, within each subgroup there are languages or dialects which lack final devoicing (dialects of English/Germanic; dialects of French/Italic; Geg dialect of Albanian; Ukrainian/Slavic; Latvian/Baltic; dialects of Farsi/Indo-Iranian; and Western Armenian).

Though modern languages are listed, there is the further possibility that languages with final devoicing are direct descendants of earlier instances of diffusion. So, for example, final devoicing in Old French is attributed to contact with Frankish (Posner 1995: 219–220), and is still found in many regional varieties of French, like that of Toulouse (Vilesy 1971). Standard Albanian lacks final devoicing, but the Northern Tosk dialect and transitional Southern Geg (Malesia e Madhe) show it; in the latter, the sound pattern is shared with adjacent Montenegrin dialects, and in both, appears to be due to earlier contact with Macedonian (Southern Slavic) (Friedman 2004). For nearly any sound pattern, synchronic type frequency will be much higher than token sound change frequency due, primarily to inheritance and contact. In assessing the frequency of sound changes like (4) then, it is important to distinguish unique reflections of the sound change in the synchronic database. In sum, while final obstruent devoicing is a common sound pattern, the sound change giving rise to it is not half as common as one might think, relying solely on the number of languages with this particular sound pattern.

2.2. *Explaining final devoicing*

Why is final devoicing (4) a recurrent sound change? And what is the phonetic source of sound change in the general typology suggested in (2)? The sound change shifting [b d g] to [p t k] word-finally is common because of common features of speech production, perception, and acquisition. In this case, consolidating the work of Ohala (1983, 1997), Steriade (1993, 1999), Blevins (2004a), and Vaux and Samuels (2004), three primary phonetic factors, one relevant domain factor, and general aerodynamic factors converge to produce common trajectories of final devoicing. These factors are summarized in (5), (6) and (7) respectively.

The first phonetic factors (5i) are the association of specific laryngeal gestures with utterance or phrase boundaries. In many languages, laryngeal spreading gestures are used to mark phrase-boundaries (5ia). When this association holds for phrase-final position, the final segment or segments of a phrase will be produced with the vocal folds spread. Ohala (1983) suggests that the spread glottal gesture resulting in final devoicing results from coarticulatory anticipation of the vocal fold configuration for non-speech during pause, which involves relaxed breathing with the vocal folds spread. However, this coarticulatory explanation does not extend to (5ib), where it is noted that many languages also use laryngeal closing gestures to mark phrase-boundaries. Stevens (2004: 5) suggests that this glottalization may serve to enhance the voicelessness of alveolars in English, but this does not explain why phrase-final nasals and vowels may be glottalized as well. In fact, there seems to be a strong correlation in many unrelated languages (e.g. Limbu, Cantonese, Korean, English) between the absence of release of a consonant, and glottal constriction. Since glottal constriction will inhibit voicing, laryngeal closing gestures may also involve neutralization of a voicing contrast in phrase-final position.

¹⁶ An anonymous reviewer remarks that, with reference to (5.i), it begs the question to 'explain final devoicing by saying that phrase boundaries are often marked by devoicing gestures.' However, the gestures in question are not specific obstruent devoicing gestures, but general laryngeal gestures which can result in sonorant devoicing, sonorant glottalization, vowel devoicing (and loss), vowel glottalization, and pitch perturbation effects. Furthermore, these effects occur at initial and final phrasal boundaries, while phonologized devoicing is typically final in the word-domain. Explaining the evolution of word-final devoicing, in part, by the high frequency of associations between laryngeal gestures and phrasal boundaries does not beg the question, but it certainly does raise additional questions for further research: Why are phrase boundaries associated with laryngeal spreading and closing gestures in so many of the world's languages?; Why is phonologization of final obstruent devoicing more common than phonologization of sonorant or vowel devoicing? While these are important questions, they are very different questions from 'Why is word-final obstruent voicing a common sound pattern?'. Finally, explaining final obstruent devoicing in terms of the factors in (5) and (6) makes predictions that other models do not, as detailed below, providing greater explanatory adequacy than competing innatist proposals.

See Kenstowicz et al. (2003) for further potential phonetic factors affecting the perceptibility of obstruent voicing.

(5) Phonetic sources of final devoicing

- i. Laryngeal gestures at phrase-boundaries¹⁶ (Blevins to appear b)
 - a. Laryngeal spreading gestures are used in many languages to mark phrase-boundaries. These gestures may result in phrase-final devoicing often with aspiration. Since the end of a phrase is the end of a word, [p t k] will occur word-finally at the phrase boundary. This gives rise to voiced and voiceless variants from which CHOICE can take place. (See also Ohala 1983; Vaux & Samuels 2004).
 - b. Laryngeal closing gestures are used in many languages to mark phrase-boundaries. These gestures may result in phrase-final devoicing. Since the end of a phrase is the end of a word [p' t' k'] will occur word-finally at the phrase boundary. This gives rise to voiced and voiceless variants from which CHOICE can take place.
- ii. Phrase-final lengthening (Blevins, 2004a: 104–105)
Segmental lengthening occurs under phrase-final lengthening. Lengthening of [b d g] can give rise to spontaneous devoicing; length can also result in [p t k] percepts. In the first case, voicing decays as intraoral air pressure rises in the stop. In the second case, a percept of voicelessness is based on longer durations of voiceless stops as compared to voiced stops.
- iii. Absence of audible release (Steriade 1993, 1999)
Voicing contrasts in some languages are cued by release features present in the C-V or C-R transition. In final position and before non-sonorant consonants, where consonants may not be released, these features may be absent, imperceptible, or difficult to perceive. Sound change via CHANGE results in neutralization of laryngeal release features finally, and in pre-obstruent position.

(6) Overgeneralizing phrase-to-word domains

Sound patterns may evolve from phrase-based to word-based due to dominance effects of single-word utterances in early language acquisition. Up to 60% of children's early words are words that parents use frequently as single-word utterances (Ninio 1992, 1993; Brent & Siskind 2001). Interpreting phrase-final effects as word-based effects will result in word-final devoicing.

(7) Aerodynamic Voicing Constraint (Ohala 1997)

Voicing requires: (i) vocal cords adducted (lightly approximated at midlines) and (ii) air flowing through the vocal folds. Consequences of this are:

- a. Voicing is inhibited on obstruents
- b. Factors favoring obstruent voicing are:
 - i. shorter closure duration
 - ii. larger oral cavity
 - iii. active expansion of oral cavity
(via larynx lowering, jaw lowering, augmenting velum elevation)
 - iv. velic leakage

Another phonetic source of final devoicing is phrase-final lengthening (5ii). In at least some languages, final lengthening has been shown to result in significant lengthening of final consonants (e.g. Berkovits 1993 for Hebrew). Given that voicing in oral stops will spontaneously decay with rise of intraoral air pressure, the longer the oral stop, the more likely it will end in voicelessness. Lengthening may also result in longer stop durations which result in voiceless stop percepts.

A phonetic factor resulting in possible devoicing, but more commonly in neutralization of aspirated and ejective release is the absence of release in phrase-final, word-final or pre-consonantal position (5iii) (Steriade 1999). If one primary cue for the voicing contrast in a particular language is VOT, or some other feature present in audible release, then the absence of such cues will result in neutralization. Notice that this particular factor does not extend to fricatives, where voicing tends to be cued segment-internally, and does not predict (phonetic) devoicing of sonorants as per (5ia), phonetic laryngealization of sonorants as per (5ib), or devoicing of the full class of obstruents, including fricatives (5ii).

The factor in (6) is secondary in the sense of not constituting a phonetic source of devoicing, but predicting directionality. In the course of language acquisition, a child must start with phrasal input, and segment such phrases into component words. Given identifiable stages where most early words are used as single-word utterances in parents speech, it is possible for children to interpret phrase-final sound patterns as word-final ones. For sound changes originating with phrase-final laryngeal

gestures and lengthening (5i, ii), the direction of final-devoicing sound patterns is predicted to be utterance > phrase > word > syllable.¹⁷

A final general factor in devoicing relates to aerodynamic properties of voicing. Ohala's Aerodynamic Voicing Constraint and its consequences are summarized in (7). These general factors show themselves in recurrent aspects of obstruent inventories (e.g. the fact that velar/uvular voiced stops are more likely to be missing from stop inventories than coronals or labials) and are expected to interact with the phonetic sources of voicing outlined in (5). In particular, all else being equal, devoicing of obstruents should be more likely in dorsals than coronals, and more likely in coronals than labials, due to the differing oral cavity air volumes produced during stop closure at these different points of articulation (7b, ii).

The factors in (5)–(7) are meant to explain the (multi)genesis of final devoicing sound patterns as instances of the recurrent sound change in (4). As with any other recurrent sound pattern, however, there is also the possibility that the pattern is directly inherited, the result of language contact, or accidentally similar to one resulting from (4).

2.3. *Predicting aspects of final devoicing*

Evolutionary Phonology explains sound patterns like those in Table 2 in terms of the common sound change in (4). This sound change, in turn, is argued to be the consequence of the interacting phonetic and domain factors in (5)–(7). Explaining final devoicing in terms of these phonetic and domain factors results in a range of predictions, listed in (8), that do not follow from alternative synchronic phonological treatments (e.g. Chomsky and Halle 1968; Kenstowicz and Kisseberth 1979; Lombardi 1994, 1995, 2001).

¹⁷ This historical domain trajectory has been suggested for the evolution of lexical stress patterns from phrasal intonation patterns (Hyman 1977: 40–47; Rehg 1993), and the evolution of word-final vowel shortening from phrase-final devoicing (Myers and Hansen, to appear). This differs from the position advocated by Bybee (2001: 143), that word-boundary phenomena “originate from phonetic conditioning that is not restricted, and that applies both word-internally and between words.”

- (8) Predictions of Evolutionary Phonology regarding final devoicing
- a. Final devoicing is predicted to be a *common* sound pattern
 - b. Final devoicing is predicted to have recurrent stages. In the early stages:
 - i. final devoicing will be gradient and variable
 - ii. final devoicing will only occur before pause, or phrase-finally
 - iii. final devoicing will be sensitive to aerodynamic properties
 - c. Phonologization may reflect domain properties. More specifically:
 - i. final devoicing may occur phrase-finally, but not word-finally
 - ii. final devoicing may occur word- but not syllable-finally

The first prediction (8a) is that final devoicing will be a common sound pattern, occurring with high frequency in the world's languages. I have already made general comments regarding (8a). Where inheritance by descent and contact can be ruled out, common synchronic sound patterns are those associated with common phonetically based sound change. Final devoicing may be expected to be even more common than other sound patterns with unique phonetic sources, because, under (5), it has multiple potential phonetic sources as opposed to a single phonetic source. One goal of standard Generative and Optimality theories is to define the limits of grammar, – what is and is not possible. Modern typological approaches like Evolutionary Phonology go farther, attempting to define why particular patterns occurs where and when they do. Final devoicing is not only a possible phonological sound patterns, but, given its multiple phonetic sources, one which will have a high frequency of genesis.

A second prediction is that final devoicing will show recurrent stages of genesis (8b). In the early stages, it should be gradient and variable, since its seeds are other phonetic properties which are gradient and variable. Representative data supporting the recurrent stages in (8b) are shown in (9i–iii) respectively. Again, the evolutionary approach contrasts with purely synchronic treatments of final devoicing, where no predictions are made regarding recurrent stages of development.

(9) Recurrent stages in final-devoicing

- i. In early stages, final devoicing is gradient and variable
 - GULF ARABIC/Semitic (Holes 1990: 261):
tendency to devoice voiced plosives in utterance-final position
 - IRAQW/Cushitic (Mous 1993: 38):
voiced stops are optionally devoiced word-finally
 - PERSIAN/Indo-Iranian (Mahootian 1997: 288)
Voiced series /b d j g/ partially devoice word-finally.
 - HAISLA/Wakashan (Lincoln & Rath 1986: 11):
“Word-finally, plain plosives other than /d/ are usually voiceless . . . /d/ on the other hand, . . . exhibits free variation between variants with and without voicing . . .”
 - SOUTHERN LURI/Indo-Iranian (Anonby 2003: 59):
2nd consonant in a cluster is partially devoiced at the end of an utterance
- ii. In early stages, final devoicing may only occur before pause, or phrase-finally
 - GULF ARABIC/Semitic (Holes 1990: 261):
tendency to devoice voiced plosives in utterance-final position
 - SOUTHERN LURI/Indo-Iranian (Anonby 2003: 59):
2nd consonant in a cluster is partially devoiced at the end of an utterance
 - NIGERIAN ARABIC (Owens, 1993: 21) Voiced non-sonorants are devoiced before pause
- iii. In early stages, final devoicing may be sensitive to aerodynamic properties
 - FRISIAN ca. 1900/Germanic (Tiersma 1985: 30)
/g/ is devoiced finally, but not /b, d/.
 - TONKAWA/Isolate of Central Texas (Hoijer 1933: 4)
/g/ is devoiced finally, but not /b, d/.
 - HAISLA/Wakashan (Lincoln & Rath 1986: 11):
Word-final devoicing/frication of consonants posterior to /d/; but variable devoicing of /d/ (no word-final /b/).

A third set of predictions relates to the phonologized domains of final devoicing. Because phonetic sources of devoicing include phrase-final laryngeal gestures and phrase-final lengthening (5i, ii) which are not present

at all word-boundaries, there should be cases of final devoicing which occur phrase-finally but not word-finally (8.c.i). Data summarized in (9i–ii) support this prediction.

At the same time, given the interpretation of whole phrases as words in early stages of language acquisition (6), there should be languages where voicing occurs word-finally but not syllable-finally (8.c.ii). Some examples of this pattern are given in (10). The patterns in (10) have not played a central role in modern theoretical treatments of final devoicing and general laryngeal neutralization (e.g. Steriade 1999), and syllable-based treatments of laryngeal faithfulness (Lombardi 1994, 1995, 2001) incorrectly rule them out of the factorial typology.¹⁸ Note that in the case of Dhaasanac (10a), voiced implosives are devoiced word-finally, giving rise to voiceless glottalized stops which do not occur elsewhere in the language. This sort of change is noteworthy from a general markedness perspective, since implosives inhibit devoicing when only aerodynamic factors are considered (7iii). The general pattern is highly suggestive of some other phonetic factor, possibly one not even considered in (5)–(6).

(10) Word-final (but not syllable-final) devoicing

a. DHAASANAC/Cushitic (Tosco 2001: 19–20):

Non-final	b	ḃ	t	d	ḏ	k	g	ḡ
Final	p	ʔp	t	t	ʔt	k	k	ʔk
	duf.mu					ked.mu		
	'round calabashes'					'small ko calabash'		
	e.kod.som					kud.fu		
	'bells'					'ankles'		

b. CHADIC ARABIC/Semitic (Zettner & Tourneux, 1986: 15–16)

Non-final	b	t	d	k	g	s	z	c	j	x	ɣ
Final	p	t	t	k	k	s	s	c	c	x	x
	we.he:d.ku					za:t.ku					
	'vous seuls'					2pl, masc. strong pronoun					
	we.he:d.ki					za:t.ki					
	'toi seule'					2sg, fem. strong pronoun					

c. MALTESE/Semitic (Borg & Azzopardi-Alexander 1997: 307)

All consonants can occupy word-final position, except
/b d g z v dz/
ki.te[p] 'he wrote' ki.ti[b].lek 'he wrote to you'

¹⁸ As with any Optimality account, ad hoc constraints can be invoked to result in the attested patterns. In this case, a constraint barring voiced obstruents from word-final position would do the job, though no such constraint is suggested in Kager (1999) or other textbook treatments.

2.4. *Predicting the rarity of final voicing*

The evolutionary account of final devoicing proposes no innate phonological constraints on the distribution of voiced obstruents syntagmatically or paradigmatically. The recurrent sound pattern of final devoicing is a result of general convergence. The phonetic factors in (5) and (7) result in the emergence of word-final obstruent devoicing via phonologization.¹⁹ Phonologization occurs when the variation induced by these phonetic processes results in a shift in ‘best exemplar’ of the category in question, an instance of CHOICE, or when misperception results in recategorization of voiced obstruents as voiceless, an instance of CHANGE. Under this account, nothing excludes the inverse process of final obstruent voicing from the grammar of a natural language. Rather, final obstruent voicing is predicted to be rare because there is no single documented phonetically natural process which would yield final voiced obstruents to the exclusion of voiceless obstruents, and there are few combined natural developments which yield regular final obstruent devoicing patterns.

In contrast to this account, regular final obstruent voicing is ruled out under certain innatist approaches (e.g. Kiparsky 2004) where a preference for voiced over voiceless obstruents in word- or syllable-final position cannot be stated or formulated. This is due to the analysis of final obstruent devoicing as a consequence of universal phonological markedness scales: voiced obstruents are universally marked in contrast to voiceless ones, so that positions or contexts showing preferences for unmarked members cannot show a preference for voiced obstruents over voiceless ones. Kiparsky (2004) views the failure to rule out final voicing from phonological grammars as a weakness of the evolutionary approach. In his view, “... it is easy to construct scenarios, that, unchecked, would produce ... coda neutralization in favor of the marked feature value”, so

¹⁹ The relationship between word-final devoicing and syllable-final devoicing is an interesting one, worthy of further study. Since words and syllables both constitute production units, and since syllables may be the smallest possible production units in some languages, it is possible that the laryngeal articulatory score for ‘end of word’ is extended to ‘end of syllable’ when syllables are viewed as minimal prosodic words. However, despite common impressions, very few languages have sound patterns that can only be described as syllable-final devoicing. Catalán is one of these (Blevins 2003; Wheeler, 2005).

that the absence of final voicing sound patterns in spoken languages is unexplained. The two scenarios he suggests are shown in (11).

- (11) Two potential pathways to sound patterns of final obstruent voicing
- i. final degemination followed by the transposition of a geminate/singleton opposition into a voiceless/voiced one
 - ii. intervocalic obstruent voicing followed by final vowel loss

Here I briefly outline what appear to be languages with sound patterns and historical developments closest to those outlined in (11). Before turning to these facts, however, three points are noted which make the scenarios in (11) much less likely to result in regular final obstruent voicing than might be apparent.

First, in both cases, it is necessary that the language have no other historical sources for word-final voiceless obstruents. A second point is that the transposition of the geminate/singleton opposition to a voiceless/voiced opposition in (11i) is a context free sound change which itself appears to have a phonetic basis: such a change occurs when the geminate segment is typically voiceless and the non-geminate typically partially or fully voiced. But what process would give rise to a voiced short segment following the loss of final vowels? If post-vocalic voicing is what is imagined, then the two cases fall together, as both requiring post-vocalic (or intervocalic) voicing. This brings us to the third important point. Postvocalic and intervocalic voicing are phonetic correlates of general leniting sound changes where shorter durations and lax or more incomplete closure is involved (LaVoie 2002, Kirchner 2004). However, the correlation of voicing with ‘lax’ (as opposed to ‘voiced’) consonants, allows one to dispense of the sound pattern as an instance of final obstruent voicing. This last factor lowers the probability of (11.ii) greatly, since most languages with true voicing contrasts will allow the voiced series to be phonetically described as ‘lenis’ (Jansen 2004). Keeping all of these factors in mind, it is still possible to identify potential cases of final voicing which arise in one of these two ways.

The first case of potential final obstruent voicing is the sound change in Proto-Italic responsible for the shift of Proto Indo-European *-t > Proto-Italic *-d, as in 3sg past -d (Sihler 1995: 228–29). While there are only a few morphemes for which the sound change is attested, there is no

evidence in this case against a general final obstruent voicing process. Intervocalic voicing in sandhi is attested, making (11.ii) a potential source of change.

A second case where many more facts are available is the case of final voicing in Welsh. Wells (1979) presents a detailed account of the opposition between /p t k/ and their ‘voiced’ counterparts /b d g/. Phonetically, Wells (1979: 344) describes the opposition as “more accurately a matter of fortis vs. lenis: word-initially the most obvious difference is strong aspiration of /p, t, k/, while word-finally /b, d, g/, although not necessarily involving vibration of the vocal cords, are nevertheless clearly weaker than the phonologically /p, t, k/.” Already then, there is a question of whether the phonological contrast is of the relevant type.

In word-final position, the contrast between these two series is neutralized (within the native Welsh vocabulary), with word-final plosives realized as “devoiced lenis, phonetically similar to the initial [b, d, g]” (op cit. 346). Of interest is the fact that native speakers agree in identifying these final obstruents as instances of the /b d g/ category. Due to old borrowings, near-minimal pairs occur, but in all cases, like those in (12), the voiceless or fortis consonant follows a short vowel, while the voiced or lenis consonant follows a long vowel.²⁰

(12) Predictable distribution of final /b d g/ vs. /p t k/ in Welsh
(Wells 1979: 347)

Short vowel + fortis	Long vowel + lenis
[map] /map/ ‘map’	[ma:b] /mab/ ‘son’
[brat] /brat/ ‘apron; rag’	[bra:d] /brad/ ‘treason’
[dɔt] /dot/ ‘dot; vertigo’	[do:d] /dod/ ‘to come’

Wells demonstrates convincingly that vowel length and obstruent voicing are contrastive in other environments, and debates the issue of whether to posit a decidedly unnatural rule voicing consonants after long vowels, or a more natural process lengthening vowels before voiced consonants. In

²⁰ The only exceptions to this general pattern are seeming spelling pronunciations (found only in formal, literary Welsh), a small class of function words, and recent loans from English. See Wells (1979: 354–58) for details.

the end, he strongly endorses a third proposal, namely that voiceless [p, t, k] be treated as underlying geminates, and [b, d, g] as singletons, with vowel lengthening occurring when a vowel is followed by no more than one consonant.

However, what is relevant in this case, is not the correct synchronic analysis, but the set of facts themselves. If not for the influx of loans from English and Irish many centuries ago (op cit. 347), as well as more recent loans presenting exceptions to the patterns in (12), all Welsh words ending in obstruents would observe the V:D pattern, – a surface instance of final voicing. Accidents of history have dirtied the waters, but the possibility allowed in evolutionary frameworks, and outlined in (11i) may actually be attested.

Another potential example of final voicing is found in Somali (Saeed 1999; Edmonson, Esling and Harris 2004). As suggested in (13), final voicing appears to be the result of intervocalic voicing followed by final vowel loss (11ii). Somali oral stops and their positional allophones are shown in (14).

Although it would be accurate to treat /t k/ as aspirated in contrast to the unaspirated /b d g/, the fact that allophones of /b d g/ are voiced in all positions with the exception of final position when they are glottalized and unreleased, suggests that voicing is a phonological feature of the /b d g/ series. Of particular importance is the fact that in slow careful speech, the same final stops are produced as voiced with schwa offglides, suggesting indeed that the voiceless glottalized allophones are variants of phonologically voiced segments. Once this is granted, the alternations in (15) must be interpreted as instances of word-final voicing.

- (13) SOMALI final voicing from historical intervocalic voicing + final vowel loss (cf. Ehret 1980)
- i. Intervocalic voicing: p t k > b d g/V_V
 - ii. Final vowel loss: V > Ø/_#
- Proto-Southern Cushitic *k'ut- 'dig' Somali *qod* (<*qodV)
- (14) SOMALI oral stops (Saeed 1999; Edmonson, Esling and Harris 2004)
- | | | | | | | |
|----------------------------------|---|---|---|---|---|----------|
| Voiced obstruents | b | d | ɖ | g | G | b: d: g: |
| Voiceless (aspirated) obstruents | | t | | k | | |

Obstruent distribution/positional allophones (Edmonson, Esling & Harris 2004)

Voiced obstruents /b d g/:

initial	partially voiced stop
medial	voiced fricative
final/careful speech	voiced with schwa offglide
final/normal	voiceless glottalized
medial geminate	voiceless glottalized + partially voiced stop

Voiceless obstruents /t k/:

syllable-initial only	voiceless aspirated
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(15) SOMALI word-final voicing (Saeed 1999: 24, 27)

/arak-/ 'to see'	arkay '(I) saw'	árag 'see!'
/gunut-/ 'to knot'	guntay '(I) knotted'	gúnud 'knot it!'
/ilik-/ 'tooth'	ilkó 'teeth'	ílig 'tooth'
/adak-/ 'hard'	adkaa 'hard-PST'	adág 'hard'

compare:

/edeg-/ 'lamb pen'	edgó 'lamb pens'	édeg 'lamb pen'
gor 'vulture'	gorgor 'vultures'	
dir 'send'	dirdir 'send rep.'	
ayáan 'good luck'	ayaandarró 'bad luck'	
	aayadó 'miracles'	aayád 'miracle'

Though the most salient phonetic feature distinguishing voiceless /t k/ from voiced /d g/ in Somali is the presence of aspiration in the voiceless series, the voiced series is best analysed as phonologically [voiced] given the distribution of voicing summarized in (14). In particular, the ability of speakers to produce fully voiced final stops in careful speech suggests that voicing is a phonological feature of these sounds. If all phonetic details are taken in to account, we could analyse the current sound patterns of Somali as those of final voicing, with incipient word final-devoicing due to final glottalization as described in (5i.b).

Many Uralic languages have undergone intervocalic weakening processes, creating environments where loss of word-final vowels could give rise to a final voicing pattern. In at least one language, Tundra Nenets, a voicing or fortis/lenis contrast exists for obstruents, but in word-final position, the only possible consonants are sonorants /l r m h ?/ and /b/ (16)–(17). Although the distribution of /b/ follows from historical post-

vocalic obstruent ‘weakening’, synchronically, voiced and voiceless stops contrast intervocalically, as in the minimal pair *yata/yada* in (18). Synchronically, then, there is no evidence of an automatic process of post-vocalic obstruent voicing. The distribution in (17) reflects, for *p/b*, a static instantiation of final/coda voicing and/or word-initial devoicing.

- (16) CENTRAL-EASTERN TUNDRA NENETS/Uralic (Salminen 1998, 1992)

Oral stops: /p py b by t ty d dy k/

Possible word-final consonants: /l r m h ? **b**/

- (17) TUNDRA NENETS oral stop distribution (Salminen 1998: 524)

#_V	p , py	t, ty	
C_V	p, py	b , by	t, ty k
V_V	p, py	b , by	t, ty d, dy k
V_C		b	
V_#		b	

- (18) TUNDRA NENETS postvocalic obstruent weakening, plus glottal strengthening (Salminen, 1997: 43–44, 71)

Stem	Nom. sg	+ /-ta/ ‘poss. nom.sg 3sg’
/ya-/ ‘earth’	ya	yada
/yam-/ ‘sea’	yam	yamta
/yar-/ ‘side’	yar	yarta
/yaʔ-/ ‘piece of hair’	yaʔ	yata
/yaḥ-/ ‘soot’	yaʔ	yanta
/ŋop-/ ‘one’	ŋob	ŋobta (cf. moderative ŋopoyə ‘the one’)

In many languages with distributional constraints of this type, loan word phonology provides evidence for the active nature of such constraints in the grammar. In Tundra Nenets, loans provide evidence for both the initial restriction to /p/ (19i) and the final restriction to /b/ (19ii, iii). The loans in (19iv) also argue against a synchronic post-vocalic voicing process, since post-vocalic /p/ and /b/ are both rendered faithfully. In some, evidence from loans provides limited support for a final-voicing pattern in Tundra Nenets, albeit one limited to neutralization of the single contrast between /p/ and /b/. Again, as with

Welsh, one might discard this example, due to the possibility of analysing the contrast of /p/ vs. /b/ as one of fortis/lenis as opposed to voicing.

- (19) TUNDRA NENETS restrictions on consonantal phonotactics are observed in loans, including active voicing of final /p/ to /b/ (Salminen 1992)
- i. initial devoicing

p angkor, p akor ‘gaff’	<	b agór [29, 127]
p ayənâ ‘sauna’	<	b áina [30]
p orə ‘wooded country’	<	b or [31]
p akəlasəkâ ‘flask’	<	b aklázhka [5]
 - ii. syllable-final voicing

xorə b ko ‘box’	<	koró[p]ka
təru: b kâ ‘cigarette, pipe’	<	trú[p]ka ‘pipe’ [M 499; Oks 499]
yubkâ ‘skirt’	<	yú[p]ka [p. 14]
xobtočyəkâ ‘jacket, blouse’	<	kóftočhka [p. 13]
 - iii. final/medial epenthesis

popə ‘priest’	<	pop [86]
---------------	---	----------
 - iv. no change (VpV showing that ii. is *not* post-vocalic voicing)

lapâ ‘paw’	<	lápa [135]
xâpu:sətâ ‘cabbage’	<	kapústa [p. 13]
xapitanə ‘ship captain’	<	kapitán [p. 13]
turubâ ‘chimney’	<	trubá [53]
pulyəkâ ‘bullet’	<	púl’ka

A final example of synchronic final obstruent voicing is found in Lezgian as described by Haspelmath (1993), and analysed by Yu (2004). Laryngeal contrasts for Lezgian oral stops are shown in (20). Here I will only briefly review the analysis presented in Yu (2004) in order to address the potential reanalysis suggested by Kiparsky (2004).

- (20) LEZGIAN, GÜNE DIALECT/Nakh-Daghestanian (Haspelmath 1993, Yu 2004)

some oral stops:	aspirated	T ^h	p ^h	t ^h	k ^h	k ^{hw}
	voiced	D	b	d	g	g ^w
	unspirated	T	p	t	k	k ^w
	ejective	T’	p’	t’	k’	k’ ^w

(21) Lezgian realizations of unaspirated stop series

- i. Unaspirated voiceless stops occur only in pre-vocalic/approximant pre-tonic position, and after voiceless stops or fricatives.

Prevocalic pre-tonic	<i>tar</i>	‘tree’ (cf. <i>t^har</i> ‘tara, musical instrument’)
Pre-approximant	<i>tsek^w-re</i>	‘ant.ERG’ (cf. <i>qudrat</i> ‘force’; no contrast with T ^h)

After voiceless stops/fricatives *k^htab* ‘book’ (no contrast)

- ii. They are voiced word-finally in monosyllables (including compounds)

<u>Prevocalic, pretonic (plurals)</u>	<u>Word-final monosyllables (absolute sg)</u>
<i>rapár</i>	<i>rab</i> ‘needle’
<i>jatár</i>	<i>jad</i> ‘water’
<i>mukár</i>	<i>mug</i> ‘nest’
<i>pakwár</i>	<i>pagw</i> ‘side, rib’
<u>Prevocalic pretonic</u>	<u>Word-final (compounds)</u>
<i>xp-er</i> ‘sheep.PL’	<i>xeb-mal</i> ‘animal-cattle’
<i>qap-uni</i> ‘box.ERG’	<i>qab-mab</i> ‘boxes and similar things’
<i>gat-u</i> ‘summer.ERG’	<i>gad-di</i> ‘all summer’

- iii. They are aspirated elsewhere [ambiguous /T/, /T’/ vs. /T^h/]

<u>/#T’V_</u>	<u>Post-tonically</u>
<i>k’ut^ha</i> ‘hammer’	<i>nek^h</i> ‘milk’ (cf. <i>nek’er</i> [MH], <i>neker</i> [AY; K&K] ‘milk-abs.pl’)
<i>c’ak^hul</i> ‘feather’	<i>berék^hat^h</i> ‘blessing’

As shown in (21) there are a range of distributional realizations for the unaspirated voiceless stop series in Lezgian. Yu (2004) shows that final voiced stops like those in (21ii) which alternate with medial voiceless stops are somewhat longer than non-alternating voiced stops.²¹ The underlying series with their schematic surface realizations are illustrated in (22).

²¹ The phonetic data is from one speaker from Maxachkala, Daghestan.

- (22) Phonetic surface values for Lezgian stops non-finally and finally
-
- (after Yu 2004)

	V	V]wd	
a.	/D/	D	D
b.	/T'/	T'	T'
c.	/T ^h /	T ^h	T ^h
d.	/T/	T	D: N.B. Kiparsky (2004) suggests /D:/
e.	/T ₂ '/	T'	D: N.B. Yu (2004) suggests /T/
f.	/T ₃ '/	T' (GÜNE)	T ^h N.B. Yu (2004) finds surface T/T ^h alternations

The question which arises is how to account for the apparent alternation schematized in (22d). While Yu (2004), following Haspelmath (1993) suggests a rule of final obstruent voicing, Kiparsky (2004: 20) argues that there is no reason why /T/ “could not equally be /D:/ which is conversely shortened and devoiced in onset position ... so this solution amounts to positing onset degemination and onset fortition in Lezgian, which are both eminently natural processes.” There are three problems with Kiparsky’s suggestion. First, word-initial onset position is typically a “strong” position in OT accounts; for *devoicing* to take place in Lezgian, word-initial position would need to be treated as “weak”, parallel with coda position in Dutch or Catalán. A second problem with Kiparsky’s analysis is that it requires positing underlying voiced geminate obstruents but no voiceless geminate obstruents. As far as I know, there are no languages which are described as having parallel geminate inventories. Finally, and most seriously, Kiparsky’s “onset degemination and onset fortition” must be extended to the unnatural context of pre-approximant coda to account for alternations like *tsegw* ‘ant’, *tsekw-re* ‘ant.erg’. In sum, Güne Lezgian appears to have regular word-final voicing of /T/, with phonetic maintenance of intrinsic pre-existing length contrasts (voiceless stops longer than voiced stops).

The synchronic alternations in Lezgian arose from a series of natural sound changes (Yu 2004), including pre-tonic gemination and subsequent degemination. The modern voiceless series which voices finally was historically voiced, and subject to post-tonic gemination + devoicing. Only mono-syllabic roots in modern Lezgian show these alternations, because these are the only roots where stress shifted from first to second syllable

under suffixation. As with the cases discussed earlier, an indirect evolutionary path gives rise to the apparent surface patterns of final obstruent voicing.

As noted earlier, within the evolutionary approach, nothing excludes patterns of final obstruent voicing from grammars. Final voicing is predictably rare since, unlike final devoicing, there is no single documented phonetically natural process giving rise to it. In addition, there are few combined natural developments which yield regular final obstruent voicing, especially when the ‘lenis’ nature of intervocalic voicing processes is taken into account. Rare final voicing sound patterns undermine universalist approaches which prohibit final obstruent voicing, and strengthen the view of universal tendencies as emergent properties of grammar.

2.5. *Understanding phonological stability*

Given the multiple pathways to final devoicing summarized in (5)–(7) it seems reasonable to ask why regular final obstruent devoicing is not found in all languages, or even most languages. Within the evolutionary approach, final obstruent devoicing is expected to be extremely common, due to the factors in (5)–(7), but not universal, since, as stated in (7b), a range of physical adjustments can result in sustaining obstruent voicing for normal obstruent durations.

It is interesting, in this context, to note that there is an apparent correlation between languages lacking evidence of final devoicing and the existence of medial long (geminate) voiced obstruents. Languages which have both medial voiced geminate obstruents and which maintain final voicing contrasts include Cairene Arabic (Semitic, Watson 2002); Hungarian (Uralic, Abondolo 1998b); Isnag (Austronesian, Barlaan 1995); and Kunuz Nubian (Nilo-Saharan, Abdel-Hafiz 1988). In these cases, it is possible that the phonetic adjustments used to maintain voicing in intervocalic voiced geminates are also used in final voiced stops, inhibiting the effects of factors in (5)–(7).

This apparent correlation brings up a more general topic of theoretical interest in the study of sound patterns as reflections of sound change. Where certain sound changes are highly frequent (e.g. loss of medial unstressed vowels, nasal place assimilation in VNVCV, final obstruent devoic-

ing), can we identify independent language-internal or other factors which enhance the phonological stability of the sound pattern in question? One hypothesis in Evolutionary Phonology is that paradigmatic contrast can play a role in phonological contrast maintenance (Blevins 2004a: 204–09). Another is that independent phonetic contrasts like the singleton/geminate voicing contrasts noted above, can enhance phonological stability in related segment types (Blevins 2004a: 209–11). Within purely synchronic phonological accounts, where potential relationships between sound patterns and sound change are not a focus of study, questions of stability rarely arise. In some cases, this may result in missed generalizations and misanalyses as with McCarthy's (1986) analysis of antigemination effects as a consequence of the Obligatory Contour Principle (Odden 1988, Blevins 2005a).

3. Theoretical synopsis

The typological case study of final devoicing in section 2 is not meant to be a definitive treatment of the subject within Evolutionary Phonology: it is the beginning of a theory of final devoicing, and it is used here to highlight three features of this approach which distinguish it from a range of other proposals in the literature. These three features are: the predictive value of the theory; the testable nature of hypotheses put forth; and the explanatory nature of the account. Here I briefly review these features, contrasting evolutionary approaches with contemporary alternatives.

3.1. *Predictive value*

As illustrated in section 2, theories relating recurrent sound patterns to recurrent instances of sound change make many predictions which alternative models do not. For the case of final devoicing, some predictions were listed in (8). Additional predictions are the rarity (but possible existence) of final voicing patterns, and potential associations between other phonetic aspects of voicing (e.g. articulations involved in the production of voiced geminate obstruents) and the absence of final devoicing.

A comparison of this model with traditional generative accounts of final devoicing is striking. Traditional generative accounts make few pre-

dictions outside of the following: final obstruent devoicing is a possible sound pattern; final obstruent voicing is also a possible sound pattern. Theories of markedness as added features of generative grammars (e.g. Chomsky and Halle 1968, Kean 1975) stipulate marked and unmarked values, and further propose, with little evidence that grammars with fewer marked values or features are more highly valued and easier to learn than others.

The predictive value of evolutionary approaches can also be compared with Optimality theory. As with traditional generative accounts, phonological universals can emerge from factorial typologies: if no licit constraint permutation yields an output from any input, the output is universally prohibited. Under some accounts, final devoicing is allowed, and final voicing is prohibited; under others, both patterns are allowed. However, what Optimality theory fails to account for is why certain sound patterns, like final devoicing, are very common, while others, like final voicing, are rare. Factorial typologies, like generative feature/rule schemas, provide a vocabulary for describing sound patterns and alternations, but they offer little of predictive value when we ask why a particular sound pattern occurs where and when it does.²²

3.2. *Testable nature of hypotheses*

Hypotheses relating to the distinct sources of recurrent sound patterns listed in Table 1 are testable with a range of methods. The classical comparative method allows us, in many cases, to determine genetic relationships and assess similarity by descent vs. alternatives. Parallel evolution in the form of recurrent phonetically motivated sound change results in hypotheses which are also testable. At the level of phonetic explanation, laboratory phonology can be used to explore claimed articulatory and

²² McCarthy (2002: 45, footnote 10) makes this point explicitly: “Nor is the relative frequency of certain sound patterns evidence for markedness constraints in OT. Factorial typology predicts nothing about relative frequency, distinguishing only those patterns with a frequency of zero from everything else. (Thus, factorial typology can account for what are traditionally called absolute universals but not for universal tendencies.)”

perceptual biases in human speech. As a recent example, consider the hypothesis that perception (in addition to coarticulation) plays a role in the sound change of velar palatalization whereby velars shift to alveopalatals in the context of high close vowels. Perception experiments of Guion (1998) demonstrate that there is a significant bias towards misperceiving velars as alveopalatals in these contexts, though the reverse (alveopalatals perceived as velars in complementary environments) is not found. At a broader level of analysis, the general claim that sound change may be drawn from a pool of synchronic articulatory variation (e.g. Ohala 1989, (3.iii)) can be explored by detailed phonetic studies of individual and cross-dialect variation. For example, the shift of post-tonic nasals to pre-stopped nasals in many central Australian languages suggests an earlier stage at which pre-stopped nasals were variants of plain nasals in the same environment. By finding varieties where such variants occur, the general hypothesis is confirmed. Physical constraints on speech perception and production are core areas of articulatory and acoustic phonetics, and innate aspects of linguistic knowledge continue to be tested in ever more sophisticated ways in humans and other creatures. Non-natural or external factors are perhaps the hardest to test, because of the growth of literacy, world languages, and other factors, but still possible. Consider, for example the question of whether the three-way voicing contrast described for Turkish by Kallestinova (2004) (see footnote 15) is a consequence of spelling pronunciation or not. In addition to the two speakers whose speech was analysed, one might seek out additional speakers living in remote isolated villages with very low literacy rates. If the three-way contrast is not found in these speakers, it supports the view of this three-way contrast as an ‘unnatural’ development.

For other modern phonological approaches, the majority of hypotheses are confirmed by theory-internal considerations alone, and are typically limited in suggesting one description of a particular sound pattern over another. For example, within Optimality theory, a universal constraint, **NO VOICED OBSTRUENT**, has been suggested, and used in analyses of final devoicing, among other processes. What evidence can we use to test the existence of this constraint as a component of any particular grammar, or of universal grammar as a whole? As far as I know, the evidence is wholly theory-internal. Markedness constraints of this type are hypotheses based on the patterns they are meant to explain: “The real primary

evidence for markedness constraints is the correctness of the typologies they predict under permuted ranking of the constraints in Con”, the universal constraint component (McCarthy 2002: 15).

3.3. *Explanatory nature*

As noted at the outset, a central goal of Evolutionary Phonology is to explain why certain sound patterns have the typological distributions they do. Why are certain sound patterns extremely common, while others are rare? What factors play a role in determining similar sound patterns across languages? And what is the ultimate explanation for the striking identity between recurrent context-dependent instances of sound change and recurrent alternation types across the world’s languages? In seeking to answer these questions, equal consideration is given to all sources of explanation in Table 1. An additional working premise is that principled *extra-phonological* explanations for sound patterns have priority over competing *phonological* explanations unless independent evidence demonstrates that a purely phonological account is warranted. This approach to explanation also distinguishes Evolutionary Phonology from Generative and Optimality approaches. In both of these models, the source of similarities across languages is attributed to phonological universals: distinctive features and rule formalisms in generative phonology and markedness constraints/hierarchies and faithfulness constraints in Optimality models.²³

Finally, the realm of explanation in the evolutionary approach goes beyond purely synchronic or purely diachronic models. Included here are the beginnings of explanations for common and rare sound patterns, trajectories of change, phonological stability, implicational relationships

²³ As already mentioned (e.g. footnote 5), there are Optimality approaches where phonetic explanations are imported wholesale into constraint-based ‘phonologies’. Here, the explanations proposed for various sound patterns may be similar, but the claims to grammatical instantiation are not.

Hypothesized universals are not easily testable independent of the grammars they mean to describe, as noted in the preceding paragraphs. Nevertheless, the descriptive adequacy of hypothesized universals can be evaluated. See Mielke (2004) for evidence against distinctive features as components of innate phonological knowledge.

between phonological domains, and accounts of phonological exceptionality. These and other explanations are only possible when language is viewed as a dynamic, probabilistic, evolving system, – one which is ultimately grounded in the physical realities of how we articulate and perceive speech sounds.

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References

- Abondolo, Daniel. 1998a (ed.). *The Uralic languages*. New York: Routledge.
- . 1998b. Hungarian. In Daniel Abondolo (ed.), *The Uralic languages*. New York: Routledge.
- Andruski, J., S. E. Blumstein, and M. Burton. 1994. The effect of subphonetic differences on lexical access. *Cognition* 52: 173–87.
- Anonby, Erik John. 2003. *A phonology of Southern Luri*. Munich: LINCOM Europa.
- Aslin, R. N. and D. B. Pisoni. 1980. Some developmental processes in speech perception. In G. H. Yeni-Komshian, J. F. Kavanagh, and A. C. Ferguson (eds.), *Child Phonology, Vol. 2, Perception*. New York: Academic. 67–96.
- Barlaan, Rodolfo R. 1995. Isnag. In D. T. Tryon, (ed.), *Comparative Austronesian Dictionary*, Part 1: Fascicle 1: 321–328.
- Baudouin de Courtenay, Jan. 1972. *Selected writings of Baudouin de Courtenay*, ed. E. Stankiewicz. Bloomington: Indiana University Press.
- Berkovits, R. 1993. Utterance-final lengthening and the duration of final-stop closures. *Journal of Phonetics* 21: 479–89.
- Bickel, Balthasar. 2005. Typology in the 21st century: major current developments. Paper presented at the Workshop on Typology in American Linguistics: An appraisal of the field, Linguistic Society of America Annual Meeting. Oakland, California, January 2005.
- Blevins, Juliette. 2003. The independent nature of phonotactic constraints: An alternative to syllable-based approaches. In Caroline Féry and Ruben van de Vijver (eds.), *The syllable in Optimality Theory*. 375–403.
- . 2004a. *Evolutionary phonology: The emergence of sound patterns*. Cambridge: Cambridge University Press.
- . 2004b. A reconsideration of Yokuts vowels. *International Journal of American Linguistics* 70: 33–51.
- . 2004c. Klamath Sibilant degemination: Implications of a recent sound change. *International Journal of American Linguistics* 70: 279–89.
- . 2005a. Understanding antigemination. In *Linguistic diversity and language theories*. Zygmunt Frajzyngier, David Rood, and Adam Hodges (eds.). Amsterdam/Philadelphia: Benjamins. 203–34.
- . 2006. New perspectives on English sound patterns: ‘Natural’ and ‘Unnatural’ in Evolutionary Phonology. *Journal of English Linguistics*. 34: 6–25.

- . To appear a. The role of phonological predictability in sound change: Privileged reduction in Oceanic reduplicated substrings. *Oceanic Linguistics* 44: 455–464.
- . To appear b. Consonant epenthesis: natural and unnatural histories. In Jeff Good (ed.), *Language universals and language change*. Oxford: Oxford University Press.
- . To appear c. Interpreting misperception: Beauty is in the ear of the beholder. In Maria Josep Sole, Pam Beddor, and Manju Ohala (eds.), *Experimental Approaches to Phonology*. Oxford: Oxford University Press.
- . To appear d. Phonetic explanations for recurrent sound patterns: Diachronic or Synchronic? In C. Cairns and E. Raimy (eds.), *Phonological Theory: Representations and Architecture*. Cambridge, MA: MIT Press.
- Blevins, J. and A. Garrett. 1998. The origins of consonant-vowel metathesis. *Language* 74: 508–56.
- . 2004. The evolution of metathesis. In Bruce Hayes, Robert Kirchner, and Donca Steriade (eds.) *Phonetically Based Phonology*. Cambridge: Cambridge University Press. 117–56.
- Blevins, Juliette, David Kamholz and Hans-Jorg Bibiko (compilers). In preparation. *Handbook of phonological change*. Department of Linguistics, Max Planck Institute for Evolutionary Anthropology.
- Bliese, Loren F. 1981. *A Generative Grammar of Afar*. Summer Institute of Linguistics, University of Texas at Arlington.
- Blumstein, Sheila E. 2004. Phonetic category structure and its influence on lexical processing. A. Agwuele, W. Warren and S.-H. Park (eds.), *Proceedings of the 2003 Texas Linguistics Society Conference*. Somerville, MA: Cascadilla Proceedings Project. 17–25.
- Bod, Rens, Jennifer Hay, and Stefanie Jannedy (eds). 2003. *Probabilistic linguistics*. Cambridge, MA: The MIT Press.
- Boersma, Paul. 2003. The odds of eternal optimization in Optimality Theory. In D. Eric Holt (ed.), *Optimality Theory and language change*. Dordrecht: Kluwer. 31–65.
- . 2005. Phonology without markedness constraints. Presentation given at the ICLaVE 3, Amsterdam, June, 2005.
- Borg, Albert and Marie Azzopardi-Alexander. 1997. *Maltese*. London: Routledge.
- Breen, Gavan and Rob Pensalfini. 1999. Arrernte: A language with no syllable onsets. *Linguistic Inquiry* 30: 1–25.
- Brent, Michael R. and Jeffrey Mark Siskind. 2001. The role of exposure to isolated words in early vocabulary development. *Cognition* 81: B33–B44.
- Broselow, Ellen, Su-I Chen and Chilin Wang. 1998. The emergence of the unmarked in second language phonology. *Studies in second language acquisition* 20: 261–280.
- Bybee, Joan. 1998. Usage-based phonology. In M. Darnell, E. Moravcsik, F. Newmeyer, M. Noonan, and K. Wheatley (eds.), *Functionalism and formalism in linguistics, Volume I: General papers*. Amsterdam: John Benjamins. 211–242.
- . 2001. *Phonology and language use*. Cambridge: Cambridge University Press.
- Chomsky, Noam and Morris Halle. 1968. *The sound pattern of English*. New York: Harper & Row.
- Cooper, David L. 1999. *Linguistic attractors: The cognitive dynamics of language acquisition and change*. Amsterdam: John Benjamins.
- Croft, William. 2000. *Explaining language change: An evolutionary approach*. Harlow, Essex: Longman.
- Damper, R. I. and Stevan Harnard. 2000. Neural network modeling of categorical perception. *Perception and psychophysics* 62: 843–867.

- De Boer, Bart. 1999. *Self-organization in vowel systems*. PhD dissertation, Vrije Universiteit, Brussels.
- . 2001. *The origins of vowel systems*. Oxford: Oxford University Press.
- De Chene, Brent E. and Stephen R. Anderson. 1979. Compensatory lengthening. *Language* 55: 505–35.
- Dent, M. L., F. Brittan-Powell, R. J. Dooling, and A. Pierce. 1997. Perception of synthetic /ba-/wa/ speech continuum by budgerigars (*Melopsittacus undulatus*). *Journal of the Acoustical Society of America* 102: 1891–1897.
- Edmonson, Jerold A., John H. Esling, and Jimmy G. Harris. 2004. Supraglottal cavity shape, register, and other phonetic features of Somali. Ms., University of Texas at Arlington, and University of Victoria.
- Ehret, Christopher. 1980. *The historical reconstruction of Southern Cushitic phonology and vocabulary*. Berlin: Dietrich Reimer Verlag.
- Eimas, P. D., E. R. Siqueland, P. W. Jusczyk, and J. Vigorito. 1971. Speech perception in infants. *Science* 171: 303–06.
- Ernestus, M and H. Baayen. 2003. Predicting the unpredictable: Interpreting neutralized segments in Dutch. *Lg*: 5–38.
- Everett, Daniel L. 1982. Phonetic rarities in Pirahã. *Journal of the International Phonetic Association* 12: 94–96.
- Friedman, Victor. 2004. Geg Albanian and Balkan dialectology. Paper presented at the 14th Biennial Conference on Balkan and South Slavic Linguistics, Literature and Folklore.
- Frisch, Stefan, Nathan Large and David Pisoni. 2000. Perception of wordlikeness: Effects of segment probability and length on the processing of nonwords. *Journal of Memory and Language* 42: 481–96.
- Frisch, S. A., Pierrehumbert, J. B., and Broe, M. B. 2004. Similarity avoidance and the OCP. *Natural Language and Linguistic Theory* 22: 179–228.
- Garrett, Andrew. 2005. Computational linguistic phylogeny: Problems and prospects. Paper presented at workshop on Mathematical modeling and analysis of language diversification, Harvard University.
- Garrett, Andrew and Juliette Blevins. To appear. Morphophonological analogy. In Sharon Inkelas and Kristin Hanson (eds.). *The nature of the word: Essays in Honor of Paul Kiparsky*. Cambridge, Mass.: MIT Press.
- Gessner, S. and G. Hansson. 2004. Anti-homophony effects in Dakelh (Carrier) Valence Morphology. *Proceedings of Berkeley Linguistic Society* 30. Berkeley: Department of Linguistics, UC Berkeley.
- Greenberg, Joseph. 1965. Synchronic and diachronic universals in phonology. *Language* 42: 508–517.
- . 1978. Diachrony, synchrony, and language universals. In *Universals of human language*, J. H. Greenberg, C. A. Ferguson, and E. A. Moravcsik (eds.), Stanford, CA: Stanford University Press. 61–91.
- Guerin, Françoise. 2001. *Description de l'Ingouche: Parler du centre nord du Caucase*. Munich: Lincom Europa.
- Guion, Susan G. 1998. The role of perception in the sound change of velar palatalization. *Phonetica* 55: 18–52.
- Hajak J. and J. Bowden. Taba and Roma: Clusters and geminates in two Austronesian languages. *Proceedings of the XIVth International Congress of Phonetic Sciences*. San Francisco. 1033–36.

- Halle, Morris. 1959. *The sound pattern of Russian*. The Hague: Mouton.
- Hansson, Gunnar. 2004. Long-distance voicing agreement: an evolutionary perspective. *Proceedings of Berkeley Linguistic Society* 30. Berkeley: Department of Linguistics, UC Berkeley.
- Harrison, K. David, Mark Dras and Berk Kapicioglu. 2002. Agent-based modeling of the evolution of vowel harmony. *NELS* 32.
- Haspelmath, Martin. 1993. *A grammar of Lezgian*. Berlin: Mouton de Gruyter.
- . 1999. Optimality and diachronic adaptation. *Zeitschrift für Sprachwissenschaft* 18: 180–205.
- Hayes, Bruce. 1995. *Metrical stress theory*. University of Chicago Press, Chicago.
- Hayes, Bruce and Donca Steriade. 2004. Introduction: The phonetic bases of phonological markedness. In B. Hayes, R. Kirchner and D. Steriade (eds.), *Phonetically based phonology*. Cambridge: Cambridge University Press. 1–33.
- Hewitt, B. G. 1995. *Georgian: A structural reference grammar*. Amsterdam: John Benjamins.
- Hoijer, H. 1933. Tonkawa: an Indian language of Texas. *Handbook of American Indian Languages* 3: 1–148.
- Holes, Clive. 1990. *Gulf Arabic*. London: Croom Helm.
- Hume, Elizabeth. 2004. The indeterminacy/attestation model of metathesis. *Language* 80: 203–37.
- Hyman, Larry. 1977. On the nature of linguistic stress. In L. M. Hyman (ed.), *Studies in stress and accent, Southern California Occasional Papers in Linguistics* 4: 37–82.
- Iverson, Gregory K. and Joseph C. Salmons. 1995. Aspiration and laryngeal representation in Germanic. *Phonology* 12: 369–96.
- . To appear. Filling the gap: English tense vowel plus final /ʃ/. *Journal of English Linguistics*.
- Jakobi, Angelika. 1990. *A Fur grammar*. Hamburg: Helmut Buske Verlag.
- Jansen, Wouter. 2004. *Laryngeal contrast and phonetic voicing: A laboratory phonology approach to English, Hungarian and Dutch*. PhD dissertation, University of Groningen.
- Jessen, Michael. 1998. *Phonetics and phonology of tense and lax obstruents in German*. Amsterdam: John Benjamins.
- Jessen, Michael and Catherine Ringen. 2002. Laryngeal features in German. *Phonology* 19: 189–218.
- Johansson, Lars and Eva Agnes Csató. 1998. *The Turkic Languages*. London: Routledge.
- Johnson, Keith. 1997. Speech perception without speaker normalization. In K. Johnson and J. Mullennix (eds.), *Talker variability in speech processing*. San Diego: Academic Press.
- Kager, R. 1999. *Optimality Theory*. Cambridge: Cambridge University Press.
- Kallestinova, Elena. 2004. Voice and aspiration of stops in Turkish. *Folia Linguistica* 38: 117–143.
- Kavitskaya, Darya. 2002. *Compensatory lengthening: phonetics, phonology, diachrony*. New York: Routledge.
- Kean, Mary-Louise. 1975. *The theory of markedness in generative grammar*. Doctoral dissertation. Cambridge, Mass.: Massachusetts Institute of Technology.
- Keller, Rudi. 1994. *Language change: The invisible hand in language*. London: Routledge.
- Kenstowicz, Michael. 1994. *Phonology in Generative Grammar*. Oxford: Blackwell.
- . To appear. Generative phonology. In *Encyclopaedia of Language and Linguistics*, 2nd Edition. Keith Brown, editor. Oxford: Elsevier.
- Kenstowicz, Michael and Charles Kisseberth. 1979. *Generative phonology*. New York: Academic Press.

- Kenstowicz, Michael, Mahasen Abu-Mansour, and Miklós Törkenczy. 2003. Two notes on laryngeal licensing. In Stefan Ploch (ed.), *Living on the edge: 28 papers in honor of Jonathan Kaye*. Berlin: Mouton de Gruyter.
- Kiparsky, Paul. 2004. Universals constrain change; change results in typological generalizations. Ms., Stanford. [To appear in Jeff Good (ed.), *Language universals and language change*. Oxford: Oxford University Press.]
- Kirby, Simon. 1999. *Function, selection, and innateness: The emergence of language universals*. Oxford: Oxford University Press.
- Kochetov, Alexei. 2002. *Production, perception, and emergent phonotactic patterns: A case of contrastive palatalization*. New York: Routledge.
- Kochetov, A. and C. K. So. 2005. Investigating the relation between place of articulation markedness and perceptual salience. *Proceedings of the 2005 Annual Conference of the Canadian Linguistic Association*. 1–11.
- Kohler, K. 1979. Parameters in the production and the perception of plosives in German and French. *Arbeitsberichte Institut für Phonetik Kiel* 12: 261–291.
- Kuhl, P. K. and J. D. Miller. 1975. Speech perception by the chinchilla: voiced-voiceless distinction in alveolar plosive consonants. *Science* 190: 69–72.
- Kuhl, P. K. and D. M. Padden. 1982. Enhanced discriminability at the phonetic boundaries for the voicing feature in macaques. *Perception and psychophysics* 32: 542–550.
- Labov, William. 2001. *Principles of linguistic change, Vol. 2, Social factors*. Oxford and Cambridge, MA: Blackwell.
- Ladefoged, Peter and Ian Maddieson. 1996. *The Sounds of the World's Languages*. Oxford: Blackwell.
- Lamberti, Marcello. 1986. *Die Somali-Dialekte*. Hamburg: Helmut Buske Verlag.
- Larson, Allan and Jonathan B. Losos. 1996. Phylogenetic systematics of adaptation. In M. R. Rose and G. V. Lauder (eds.) *Adaptation*. San Diego: Academic Press. 187–220.
- Liberman, A. M., F. S. Cooper, D. P. Shankweiler, and M. Studdert-Kennedy. 1967. Perception of the speech code. *Psychological Review* 74: 431–61.
- Lincoln, Neville J. and John C. Rath. 1986. *Phonology, dictionary and listing of roots and lexical derivatives of the Haisla language of Kitlope and Kitimaat, B. C. Ottawa, Volume 1*: Canadian Museum of Civilization Mercury Series.
- Lindblom, Björn. 1990. Explaining phonetic variation: A sketch of the H&H theory. *Speech production and speech modelling*, ed. by William Hardcastle and Alain Marchal. Dordrecht: Kluwer. 403–39.
- . 1992. Phonological units as adaptive emergents of lexical development. In C. A. Ferguson, L. Menn, and C. Stoel-Gammon (eds), *Phonological development: Models, Research, Implications*. Timonium, MD: York Press. 565–604.
- Lindblom, Björn, Peter MacNeilage and Michael Studdert-Kennedy. 1984. Self-organizing processes and the explanation of language universals. In Brian Butterworth, Bernard Comrie, and Östen Dahl (eds.), *Explanations for Language Universals*. Berlin: Walter de Gruyter. 181–203.
- Lombardi, Linda. 1994. *Laryngeal features and laryngeal neutralization*. New York: Garland.
- . 1995. Laryngeal neutralization and syllable wellformedness. *Natural Language and Linguistic Theory* 13: 39–74.
- . 2001. Why Place and Voice are different. In L. Lombardi (ed.), *Segmental phonology in Optimality Theory: constraints and representations*. Cambridge: Cambridge University Press, 13–45.

- Maddieson, Ian. 1984. *Patterns of sounds*. Cambridge University Press, Cambridge.
- Mahootian, Shahrzad. 1997. *Persian*. London: Routledge.
- McCarthy, John J. 2002. *A thematic guide to optimality theory*. Cambridge: Cambridge University Press.
- . 2003. Comparative markedness. *Theoretical Linguistics* 29: 1–52.
- Merrifield, William R. and Jerold A. Edmonson. 1999. Palantla Chinantec: Phonetic experiments on nasalization, stress, and tone. *International Journal of American Linguistics* 65: 303–323.
- Mielke, Jeff. 2004. *The emergence of distinctive features*. PhD dissertation, The Ohio State University, Columbus. To appear, Oxford University Press.
- Miller, J. L. 1994. On the internal structure of phonetic categories: a progress report. *Cognition* 50: 271–85.
- Moeliono, Anton M. and Charles E. Grimes. 1995. Indonesian (Malay). In Darell T. Tryon, (ed.), *Comparative Austronesian Dictionary*, Part 1: Fascicle 1: 443–457.
- Mous, Marten. 1993. *A grammar of Iraqw*. Hamburg: Helmut Buske Verlag.
- Myers, Scott. 1991. Persistent rules. *Linguistic Inquiry* 22: 315–44.
- Myers, Scott and Benjamin Hansen. To appear. Neutralization of vowel length contrasts in final position. *Natural Language and Linguistic Theory*.
- Nettle, Daniel. 1998. *The Fyem language of Northern Nigeria*. Newcastle: Lincom Europa.
- Nichols, Johanna. *Language diversity in space and time*. Chicago: The University of Chicago Press.
- Ninio, Anat. 1992. The relation of children's single word utterances to single word utterance in the input. *Journal of Child Language* 19: 87–110.
- . 1993. On the fringes of the system: children's acquisition of syntactically isolated forms at the onset of speech. *First Language* 13: 291–313.
- Odden, David. 2005. The unnatural phonology of Zina Kotoko. Ms., The Ohio State University.
- Ohala, J. J. 1971. The role of physiological and acoustic models in explaining the direction of sound change. *Project on Linguistic Analysis Reports* (Berkeley) 15: 25–40.
- . 1981. The listener as a source of sound change. In Carrie S. Masek, Robert A. Hendrick and Mary Frances Miller (eds.), *Papers from the parasession on language and behavior*. Chicago Linguistic Society, Chicago, Il. 178–203.
- . 1983. The origin of sound patterns in vocal tract constraints. In P. F. MacNeilage (ed.), *The Production of Speech*. New York: Springer. 189–216.
- . 1989. Sound change is drawn from a pool of synchronic variation. L. E. Breivik and E. H. Jahr (eds.), *Language Change: Contributions to the study of its causes*. [Series: Trends in Linguistics, Studies and Monographs No. 43]. Berlin: Mouton de Gruyter. 173–198.
- . 1990. The phonetics and phonology of aspects of assimilation. In J. Kingston and M. Beckman (eds.), *Papers in Laboratory Phonology I*. Cambridge University Press, Cambridge. 258–75.
- . 1993. The phonetics of sound change. In Charles Jones (ed.), *Historical Linguistics: Problems and Perspectives*. London: Longman. 237–278.
- . 1997. Aerodynamics of phonology. *Proceedings of the Seoul International Conference on Linguistics*. Seoul: Linguistic Society of Korea. 92–97.
- . 2005. Phonetic explanations for sound patterns. Implications for grammars of competence. In W. J. Hardcastle and J. M. Beck (eds.), *A figure of speech. A festschrift for John Laver*. London: Erlbaum. 23–38.

- Orwin, Martin. 1993. Phonation in Somali phonology. In Mohamed Abdi Mohamed (ed.), *Anthropologie Somalienne. Proceedings of the 2ème Colloque des Études Somaliennes*. 251–257.
- Oudeyer, Pierre-Yves. 2005. The self-organization of speech sounds. *Journal of Theoretical Biology*, Volume 233/3: 435–449.
- Owens, Jonathan. 1993. *A grammar of Nigerian Arabic*. Wiesbaden: Otto Harrassowitz.
- Pierrehumbert, Janet. 2000. What people know about sounds of language. *Studies in the Linguistic Sciences* 29: 111–120.
- . 2003. Probabilistic phonology: Discrimination and robustness. In R. Bod, J. Hay, and S. Jannedy (eds.), *Probabilistic Linguistics*. Cambridge, MA: MIT Press. 177–228.
- Pinker, Steven and Ray Jackendoff. 2005. The faculty of language: what's special about it. *Cognition* 95: 201–36.
- Pisoni, D. and J. Tash. 1974. Reaction times to comparisons within and across phonetic categories. *Perception and psychophysics* 15: 289–90.
- Posner, Rebecca. 1995. Contact, social variants, parameter setting, and pragmatic function: An example from the history of French syntax. In Jacek Fisiak (ed.), *Language change under contact conditions*. Berlin: Mouton de Gruyter. 217–36.
- Prince, Alan and Paul Smolensky. 1993. Optimality theory: constraint interaction in generative grammar. Ms., Rutgers University, New Brunswick and University of Colorado, Boulder. [RuCCS TR-2. New Brunswick, NJ: Rutgers Center for Cognitive Science.]
- Quigley, Edward C. 2003. Awara phonology. Master's Thesis. University of North Dakota, Grand Forks.
- Rehg, Kenneth. 1993. Proto-Micronesian prosody. In *Tonality in Austronesian languages*, J. A. Edmonson and K. J. Gregorson (eds.), Oceanic Linguistics Special Publications No. 24. Honolulu: University of Hawai'i Press. 25–46.
- Ritt, Nikolaus. 1994. *Quantity adjustment: vowel lengthening and shortening in Early Middle English*. Cambridge: Cambridge University Press.
- Robins, R. H. 1958. *The Yurok language: Grammar, texts, lexicon*. (University of California Publications in Linguistics 15). Berkeley: The University of California Press.
- Saeed, John. 1999. *Somali*. Amsterdam: John Benjamins.
- Saffran, Jenny, Richard Aslin, and Elissa Newport. 1996. Statistical learning by 8-month old infants. *Science* 274: 1926–1928.
- Sagart, Laurent. 1999. *The roots of Old Chinese*. Amsterdam: John Benjamins.
- Sakel, Jeanette. 2002. *A grammar of Mosestén*. PhD dissertation, Katholieke Universiteit Nijmegen.
- Salminen, Tapani. 1992. Russian vocabulary in Tundra Nenets. *Journal la Société Finno-Ougrienne* 84: 201–22.
- . 1997. *Tundra Nenets inflection*. Helsinki: Suomalai-Ugrilainen Seura.
- . 1998. Nenets. In D. Abondolo (ed.), *The Uralic Languages*.
- Saltarelli, Mario. 1988. *Basque*. London: Croom Helm.
- Sanders, Nathan. 2003. *Opacity and Sound Change in the Polish Lexicon*. Ph.D. dissertation. Santa Cruz: University of California, Santa Cruz.
- Schadeberg, Thilo C. 1987. Zwei areale Sprachmerkmale in Ostsudan. In Hans G. Mukarovsky (ed.), *Leo Reinisch: Werk und Erbe (Oesterreichische Akademie der Wissenschaften, Phil.-Hist. Klasse, Sitzungsberichte. 492)*. Vienna: Oesterreichische Akademie der Wissenschaften. 213–229.

- Schneider, Edgar W., Kate Burridge, Bernd Kortmann, Rajend Mesthrie, and Clive Upton (eds.). 2004. *A Handbook of varieties of English. Volume 1, Phonology*. Berlin: Mouton de Gruyter.
- Shih, Chilin. 2005. Understanding phonology by phonetic implementation. *Proceedings of Interspeech 2005*. September 2005, Lisbon, Portugal.
- Sihler, Andrew L. 1995. *A new comparative grammar of Greek and Latin*. Oxford: Oxford University Press.
- Smyth, David. 2002. *Thai: An essential grammar*. London: Routledge.
- Stampe, David. 1973. *A dissertation on natural phonology*. Doctoral dissertation. Chicago: University of Chicago. [Published by Garland Press, New York, 1979.]
- Steels, Luc. 1997. Self-organizing vocabularies. In C. Langton and K. Shimohara (eds.), *Proceedings of the 5th International Workshop on Artificial Life: Synthesis and simulation of living systems*. Cambridge, MA: MIT Press. 179–84.
- . 2000. Language as a Complex Adaptive System. In M. Shoemaker (ed.), *Proceedings of PPSN VI, Lecture Notes in Computer Science*. Berlin: Springer-Verlag. 17–26.
- Steriade, Donca. 1993. Positional neutralization. University of California, Los Angeles, Ms.
- . 1999. Phonetics in phonology: The case of laryngeal neutralization. In Matthew Gordon (ed.), *Papers in Phonology 3 (UCLA Working Papers in Linguistics 2)*. Los Angeles: Department of Linguistics, University of California. 25–145.
- Stevens, Kenneth N. 2004. Invariance and variability in speech: Interpreting acoustic evidence. Paper presented at 'From Sound to Sense', June 2004, MIT.
- Stewart, Ian. 1998. *Life's Other Secret*. New York: Wiley.
- Tiersma, Pieter Meijes. 1985. *Frisian reference grammar*. Foris: Dordrecht.
- Tosco, Mauro. 2001. *The Dhaasanac Language: Grammar, Texts, Vocabulary of a Cushitic Language of Ethiopia*. Koeln: Ruediger Koeppel Verlag.
- Vajda, Edward J. 2004. *Ket*. Munich: Lincom Europa.
- . 2005. Stress and tone in Ket. Ms., Max Planck Institute for Evolutionary Anthropology, Leipzig.
- Vaux, Bert and Bridget Samuels. 2005. Laryngeal markedness and aspiration. *Phonology* 22: 395–436.
- Vogt, H. 1958. Structure phonémique du géorgien. *Norsk Tidsskrift for Sprogvidenskap* XVIII: 5–90.
- Wang, William S.-Y. 1979. Language change: a lexical perspective. *Annual Review of Anthropology* 8: 353–71.
- Watson, Janet C. E. 2002. *The phonology and morphology of Arabic*. Oxford: Oxford University Press.
- Wedel, Andrew. 2004a. *Self-organization and categorical behavior in phonology*. PhD dissertation, The University of California, Santa Cruz.
- . 2004b. Category competition and contrast maintenance. Paper presented at the 2005 Linguistic Society of America Annual Meeting. Ms., University of Arizona, Tucson.
- Wells, John C. 1979. Final voicing and vowel length in Welsh. *Phonetica* 36: 344–60.
- Wheeler, Max. 2005. *The phonology of Catalán*. Oxford: Oxford University Press.
- Wiese, Richard. 1996. *The phonology of German*. Oxford: Oxford University Press.
- Wildgen, Wolfgang. 1990. Basic principles of self-organisation in language. In H. Haken and M. Stadler (eds.), *Synergetics of Cognition*. Berlin: Springer. 415–26.
- Yip, Moira. 2002. *Tone*. Cambridge: Cambridge University Press.

- Yavas, Mehmet. 1994. Final stop devoicing in interlanguage. In Mehmet Yavas (ed.), *First and second language phonology*. San Diego: Singular.
- Yu, Alan C. L. 2004. Explaining final obstruent voicing in Lezgian: Phonetics and history. *Language* 80: 73–97.
- Zeltner, Jean-Claude and Henri Tourneaux. 1986. *L'arabe dans le bassin du Tchad: Le parler des Ulad Eli*. Paris: Karthala.