Natural and Unnatural Sound Patterns: A Pocket Field Guide

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Natural sound patterns are those grounded in physical properties of speech, while unnatural sound patterns arguably have no such physical basis. This study provides a brief history of the study of natural and unnatural sound patterns from antiquity forward. Definitions of natural and unnatural sound patterns are examined in a range of frameworks, and as applied to both synchronic and diachronic phonology. Examples of natural and unnatural sound patterns are provided, with attempts to move beyond linguistic intuitions by providing documentation from phonetic research, psycholinguistics, and laboratory phonology of the types of sound patterns grounded in physical properties of speech. A final issue discussed is the logic and empirical for encoding naturalness in synchronic grammars. Many common and recurrent sound patterns can be explained in terms of the way humans articulate and perceive speech, but phonetic explanation should be properly segregated from grammatical description and analysis.

1. Introduction: the study of sound patterns

Phonology is the study of sound patterns of spoken human languages. In all spoken languages it is possible to discover sound patterns that characterize the form and content of words and phrases. These patterns can be divided into three basic types: patterns in contrastive sound inventories, also known as *contrasts*; patterns in the static distribution of sounds, also known as *phonotactics*; and patterns defined by the variable realization of sounds in different contexts, also known as *alternations*. Synchronic phonology investigates systems of contrasts, phonotactics and alternations at a particular point in time, while historical or diachronic phonology concerns itself with changes in these sound patterns over time.

In addition to classifying sound patterns by basic type, phonologists continue to recognize *natural* sound patterns in contrast to *unnatural* ones. Though the term 'natural' has come to mean many different things to modern phonologists, there is general agreement that 'natural' sound patterns include those grounded in physical properties of speech, where physical properties of speech include articulation and perception. Extensions of this narrow definition are considered in section 2.1, with examples of natural sound patterns provided in 2.2. Since unnatural sound patterns are those which are not natural, identifying them will depend on how natural sound patterns are defined. Definitions and examples of unnatural sound patterns are provided in section 3. Sections 2 and 3 are meant

as a brief field guide for linguists interested in identifying sound patterns as natural or unnatural. Though individuals will have divergent intuitions about the types of sound patterns grounded in physical properties of speech, there is now a wealth of documentation from phonetic research, psycholinguistics, and laboratory phonology to support or refute these intuitions.

While recognizing natural sound patterns provides firm phonetic explanations for many of the most common recurrent phonological features of the world's languages, a question that arises is whether naturalness should play a role in synchronic and/or diachronic grammatical descriptions. While most modern grammatical frameworks that address this question (e.g. Generative Phonology, Natural Phonology, Optimality Theory) answer in the affirmative, traditional diachronic approaches answer tacitly in the negative. Anderson's (1985, 346) cogent remarks on this topic are taken up in section 4, where the logic and empirical motivation of encoding naturalness in synchronic grammars is called into question. Before turning to definitions and examples of natural sound patterns, unnatural sound patterns, and the problems inherent in their grammatical encoding, a summary of treatments of natural sound patterns in the world's major linguistic traditions from earliest historical sources to the present is presented below. This bird's-eye view of the field is meant to provide the reader with an inventory of potential precursors to modern notions of naturalness, and to foster renewed appreciation of the ancient heritage of natural approaches in the study of sound patterns.

Phonology is a relatively old science, and systematic study of sound patterns is found in a part of ancient Indic, European, Chinese and Arabic traditions. The work of Pānini (c. 520-460 BCE) is known for its implicit recognition of Sanskrit phonemes, natural classes, and alternations. More explicit phonological categories are described for Ancient Greek in the work of Dionysios Thrax (170-90 BCE). Around the same time, the Tamil grammar *Tolkāppiyam* appeared, which included consonants and vowels as explicit phonological categories, contained detailed discussion of alternations, and even devoted a chapter, 'Mozhi Marabu', to phonotactic restrictions. During the Han Dynasty, Cheng Hsuan (127-200) recognized systematic differences in sound patterns between ancient and modern Chinese, and Sibawayh's treatise on Arabic, *Al-Kitab* (ca. 800 CE), covers phonological contrasts, phonotactic generalizations, and regular consonant and vowel alternations. However, it is only beginning with this last author that an explicit relationship is defined between sound patterns and properties of the natural world.

Sibawayh proposes a clear causal relationship between sound patterns and their natural phonetic basis. Rules of assimilation, weakening and elision are consistently attributed to ease of articulation and economy of effort. In some cases, the natural explanation is extremely precise. In describing cases of total consonant assimilation in which a sequence of two distinct consonants is realized as a geminate, Sibawayh remarks that "speakers find it easier to execute only one

action of the tongue to produce the two identical segments" (vol. 3, 530).[1] The realization of *h* followed by a voiced pharyngeal as a voiceless geminate pharyngeal rather than as a voiced one, is attributed to the fact that voiceless consonants are easier to articulate than their voiced counterparts (vol. 4, 450; Al-Nassir 1993, 64-65). These and many other descriptions allow us to view Sibawayh as one of the first 'natural' phonologists, where the natural sound patterns he analyses are those with phonetic motivation, grounded in the way humans produce and perceive speech.

Another major figure in the world history of natural sound patterns is Korean King Sejong (1397-1450), fourth king of the Joseon Dynasty. After sending his advisors many times to study with a greatly respected Chinese phonetician, King Sejong presented a phonetically-based alphabet to the Korean people in 1446. This alphabet, now known as 'Hangul' is phonemic, representing only the contrastive sounds of the Korean language. At the same time, it is clearly based on principles of articulatory phonetics, so that point of articulation and laryngeal mechanism are represented as features of consonant sounds. An interesting aspect of this invention was the King's belief, ultimately supported by subsequent generations of literate Koreans, that a natural phonetically-based system would be easier for people to learn than alternative writing systems. In this way, King Sejong might be one of the first scholars to associate phonological naturalness with ease of acquisition (for more on this association see 2.1.).

While Sibawayh and King Sejong provided natural accounts of synchronic sound patterns, by the 16th century, similar views of naturalness were associated with sound change as well. Chén Dì (1541-1617) discovered that regular sound change was responsible for the systematic differences in Chinese pronunciation noted by Cheng Hsuan over a thousand years earlier, and proclaimed: "It is a natural principle that the script and the sounds of language differ according to time and place".[2] Soon to follow were the early works on Indo-European sound correspondences, culminating in the 'phonetic rules' or 'sound laws' of the 19th century comparative tradition. The naturalness of these laws was assumed by most, but explicitly detailed in the work of von Raumer (1856), the Neogrammarians (e.g. Verner 1875, Brugmann 1876, Paul 1880, and Sievers 1901), as well as Baudouin de Courtenay (1895; 1910 [1972]) of the Kazan School. While the major focus was on natural articulatory explanations, perception was also occasionally mentioned (e.g. von Raumer 1856), with Baudouin (1910 [1972], 267-68) suggesting misperception as an additional source of natural sound change.

A contributing factor to the flurry of references to naturalness in the mid-to-late 19th century phonology was cross-fertilization between the linguistic sciences and the natural sciences. Lyell's *Principles of Geology* (1830),

[1] This quote is taken from Al-Nassir (1993, 58).
[2] This quote is taken from Norman (1988, 42).

Geological Evidences of the Antiquity of Man (1863), and Darwin's *The Origin of Species* (1859) and *The Descent of Man and Selection in Relation to Sex* (1871) appeared during this time. These works are notable, not only for their contemporary influence, but also for the fact that they contain analogies to linguistic theories of the time (Alter 1999). In this context, the wide range of references in the opposite direction, is, perhaps, not so remarkable, but a few are worth mentioning in the context of the 19th century authors mentioned above. Consider von Raumer's (1856) title: "Die sprachgeschichtliche Umwandlung und die naturgeschichtliche Bestimmung der Laute" (Linguistic-historical change and the natural-historical definition of sounds). Also noteworthy is Paul's (1880) account of sound change as a function of natural variation in articulation inherent to human speech, modified by natural selection or purposiveness: "Purposiveness (*der Zweck*) plays the same role as that which Darwin attributed to it in organic nature" (Paul 1880, 32 [Weinreich et al. 1968, 110]), with the direction of sound change due to the fact that it "in some respect *suits* the organs of the speaker *better*" (Weinreich et al. 1968, 111).

The view of sound change, and language evolution more generally, as a natural process continued into the 20th century. Martinet's (1960/1964, 167) position is not so different from that of Sibawayh: "Linguistic evolution may be regarded as governed by the permanent conflict between man's communicative needs and his tendency to reduce to a minimum his mental and physical activity". Similar views of sound change as phonetically motivated were expressed by the American structuralists, including Bloomfield (1933, 346ff.) and Hockett (1965). However, the study of synchronic phonology in the 20th century, both in Europe and America, was, in: many ways, curiously removed from an interest in what sound patterns are phonetically natural, and why.[3] Explicit rejection of a natural basis of phonology is found in the work of Hjelmslev (e.g. Hjelmslev and Udall 1935), while the Prague school made a distinction between 'natural markedness' and 'logical markedness' (or 'markedness' for short), with most energy invested in the study of the latter.[4] Many American structuralists and early generativists omit references to naturalness in their attempts to outline general 'discovery procedures' and formal properties of grammars. While terms like 'natural class' are suggestive, they involve formal definitions removed from phonetic content. In Halle's (1962; 1964) system, fewer features characterize more general natural classes than less general ones, while later definitions count two or more segments

[3] For a detailed account of phonology in the 20th century, see Anderson (1985). Anderson's central discussion of naturalness is on pp. 342-347.

[4] These two types of markedness are defined in Trubetzkoy (1939). Natural markedness is assigned to the member of an opposition instantiating the privative phonetic feature in question. Logical markedness, or, more commonly 'markedness', is a relation determined by aspects of a phonological system. One and the same segment may be naturally marked with respect to a feature in one opposition, and logically marked in the same (or another).

as a natural class if fewer features are required to specify the class than to specify any one member of the class (Hyman 1975, 139). The *Sound Pattern of English* (Chomsky and Halle 1968) does include a final chapter taking stock of the fact that the theory, as it stands, makes no formal contrast between natural and unnatural phonologies, and suggests a theory of markedness to remedy this.[5] However, as with Prague school markedness, markedness theory took on a life of its own, and was formally dissociated from naturalness in the phonetic sense.[6]

Two 20th century schools of phonology, however, maintained a serious interest in natural phonetic foundations, and can be seen as catalysts of renewed interest in natural sound patterns in the 21st century. One is the aptly named 'Natural Phonology', first formulated by David Stampe in the late 1960s as a direct response to inattention to naturalness within the generative tradition (Stampe 1973).[7] While the demarcation of natural processes was quite specific (see Section 2), their basis in phonetic naturalness and claimed universality have lead many researchers in modern Grounded Phonology (Archangeli and Pulleyblank 1994) and Optimality Theory (Prince and Smolensky 1993; Kager 1999; McCarthy 2002) to refer to Natural Phonology as a forerunner in these areas.[8] A distinct line of research which gathered momentum during the same period was Ohala's school of Experimental (or Laboratory) Phonology. Here, the primary focus of research was, and continues to be, underlying phonetic explanations of recurrent sound patterns (see, e.g., Ohala 1971; 1974; 1975, Ohala and Lorentz 1977, Ohala 1981; 1983).[9] Building on the Neogrammarian view, Ohala and colleagues use the laboratory to test concrete hypotheses regarding natural perceptual, acoustic, and aerodynamic bases of regular sound change. This research paradigm has been central to work in phonetically-based phonology (Hayes et al. 2004), especially Evolutionary Phonology (Blevins and Garrett 1998, Blevins 2004a; 2006a; 2006b), whose primary goal is explanation of recurrent sound patterns in the world's languages.

[5] See Hyman (1975), Chapter 5 'Phonological Naturalness' for a clear exposition of how SPE markedness theory is structured to account for natural and unnatural sound patterns.

[6] This is true of many Optimality conceptions of markedness as well, including DeLacy (2006). In this defense of markedness, in: over 400 pages, there is no discussion of naturalness *per se*. Natural explanations, where alluded to, are termed 'performance factors' (e.g. p. 351), and are seen as irrelevant (see footnote 14). See Haspelmath (2006) for general arguments against markedness as it is used in linguistic theory.

[7] Studies in Natural Phonology include Bruck et al. (1974), Stampe (1979), Donegan and Stampe (1979), and Hurch and Rhodes (1996). The first and last references are edited volumes, and include contributors from North America, Europe and other parts of the world.

[8] McCarthy (2002, 51), for example, remarks that "OT has closer affinities to Natural Phonology than to SPE".

[9] The work of Lindblom and colleagues should also be mentioned in this context. Where Ohala's attention focused on local sound change and sound patterns, Lindblom explored system-wide properties and their phonetic bases (e.g. Liljencrants and Lindblom 1972, Lindblom 1986; 1990).

All languages have sound patterns that are described as 'natural', and others described as 'unnatural'. What do these terms mean, and what is the most useful way of defining naturalness in reference to sound patterns? In the remainder of this study, I present concrete definitions of natural and unnatural sound patterns as these terms have been used in the modern phonological literature, and provide examples of sound patterns illustrating the proposed categories. Section 4 discusses the most common explanations for the existence of both natural and unnatural sound patterns in spoken human languages, and a brief critique of theories that insist that naturalness should be encoded in phonological grammars.

2. Natural sound patterns

2.1. What are natural sound patterns?

The overview above has already provided one concrete and commonly assumed definition of natural sound patterns. *Natural sound patterns are sound patterns grounded in articulatory and perceptual properties of speech*. Typically, this means that the sound pattern can be explained with reference to articulatory and perceptual properties of speech; not predicted, but understood with reference to concrete aspects of speech production and perception. Naturalness, in: this sense, can be applied to synchronic contrasts, phonotactics, and alternations, as well as to sound change. The definition above is the most common one found in the phonology literature, and the one adopted here. The following paragraphs briefly review differences between this and other definitions, and highlight reasons for adopting it.

A slight difference between the definition of naturalness above, and that proposed by, for example, Ohala (1974), is that there is no claim that the articulatory and perceptual properties of speech must be universal. The majority of fundamental results in this area are universal, but we can imagine otherwise. Consider, for example, the fact that in the majority of Australian languages, there are no contrastive fricative sounds. The most common contrastive fricatives in the world's languages are sibilants, and one might set out to explain why it is that no Australian Aboriginal language has contrastive sibilants.[10] An explanation for this has been tentatively suggested by Butcher (2006, 206-208), and while it must be viewed as a tentative hypothesis, I raise it as an example of a *natural*, but *non-universal*, account of a recurrent sound pattern. Butcher notes nearly all Aboriginal children develop chronic *otitis media* (COM), a middle ear infection, within

[10] The only indigenous languages of Australia with sibilants /s/ and /z/ are those of the Torres Straits, but these are Papuan languages. The most common fricatives in Australian languages are voiced, lenis /β/, /ɣ/ and /ð/ which do not have the intense high frequency noise typical of sibilants.

a few weeks of birth, and that, as a consequence, up to 70% of Aboriginal children have significant conductive hearing loss. While this loss is mostly in the sub-500 Hz range, it can also occur at higher frequencies, above 4000 Hz. Since the perception of fricative noise in sibilants requires attention to high frequency noise, Butcher hypothesizes that the absence of fricative/stop contrasts may be due to the fact that many Aborigines cannot perceive high frequencies due to COM. The hypothesis in question proposes a natural explanation for the absence of sibilant/stop contrasts in Australian Aboriginal languages, as defined above, since the explanation is grounded in aspects of speech perception. However, in: this particular case, the perceptual property referred to is not a universal one, but a natural pathological one.

A second and more subtle reason to exclude 'universal' from the definition of naturalness is the potential self-feeding nature of articulation and perception in the course of language acquisition. There is extensive research demonstrating that learning a language results in language-specific perceptual biases (Mielke 2003), and that such biases appear early on (e.g., Polka and Werker 1994). Mielke (2003) shows that universal as well as language-specific factors contribute to differential perception of /h/ by Turkish, Arabic, English, and French speakers. French speakers, who have little native experience in distinguishing /h/ from other sounds fare the worst. Consider now how this perceptual deficit my play a role in the course of language acquisition. If a natural sound change like *s>h (Ohala 1974, 267; Ferguson 1990) is in progress, French learners might fail to perceive [h]s, with the historic record showing a seemingly *unnatural* one-step *s > zero change. In fact, *s-loss or desibilization (preceding consonants) has occurred in many dialects of French (Hall 1949, Map 8), providing a potential instance of self-feeding perception in the course of acquisition. In sum, following suggestions of Dressler (1998, 47), Hume and Johnson (2001), and Blevins (2004a), a perception-production feedback loop in the course of language acquisition may result in language-specific aspects of articulation or perception playing an active role in sound change, which in turn gives rise to natural sound patterns.[11]

Other uses of the term 'natural' move beyond the physiology of speech to other linguistic domains. Donegan and Stampe (1979, 168-169) define the common ground of theories of Natural Phonology as "the basic thesis that phonological systems are phonetically motivated". However, from this starting point, they make an unwarranted leap by assuming that sound patterns in children's speech, which may differ significantly from adults, reflect *universal natural phonological processes* (also visible in synchronic natural alternations, and regular sound change), which may later be inhibited in the course of language development (ibid., 130-131). Three major objections to this point of view have been raised, beginning with Dressler (1974), continued in subsequent work in child

[11] For simulations making use of this feedback loop, see Wedel (to appear).

language phonology (Locke 1983, Vihman 1996), and further elaborated in Dressler (1998, 47-50) and Blevins (2004a, 227-232). The first problem with equating sound patterns in child speech to natural (adult) phonology is that many aspects of early pronunciation are due to the immature state of the articulators and undeveloped patterns of coordination among them. Given this, these aspects of articulation should be viewed as real performance problems, independent of phonological competence. A second observation that undermines the Natural Phonology position is that many common sound patterns in children's speech (e.g. context-free cluster reduction; fricatives produced as stops; total consonant harmony) are unattested or rare as sound changes or regular alternations in adult phonologies. A final piece of evidence against the universal naturalness of child phonology is that children have distinct individual strategies for overcoming their pronunciation difficulties, resulting in individual patterns which contradict others, like devoicing for one child, and voicing for another (Dressler 1974, 101, with reference to Smith 1973, 31). Much of child phonology, then, represents adult speech, transmogrified by articulatory development, where this transmogrification bears no clear relation to natural processes in adult or historical grammars.

An additional claim made by Natural Phonology as detailed in Donegan and Stampe (1979), is that there are only three types of natural phonological processes: fortition processes, lenition processes, and prosodic processes. The original idea was clearly to link this restricted typology with the functional view of sound patterns as natural outcomes of the competing forces of perceptual contrast and articulatory inertia. However, the typology is too restrictive, leaving no room for natural processes with perceptual bases, like those studied by Ohala and colleagues in the work noted above, or the perceptual metatheses detailed in Blevins and Garrett (1998; 2004).

A final association made in Natural Phonology, and carried over to Natural Generative Phonology (e.g. Vennemann 1971, Hooper 1976), is that natural processes in synchronic grammars (phonetically conditioned rules, or P-rules in Natural Generative Phonology) are automatic, insuppressible and exceptionless. At the same time, there is recognition that natural processes may be variable, and that variability may be associated with emerging sound patterns that are not yet established (Donegan and Stampe 1979, 140; Hooper 1976, 14). While the majority of automatic, exceptionless sound patterns in the world's languages are natural in the sense defined above, there are also exceptionless sound patterns that are arguably not natural. Consider intervocalic consonant epenthesis of [ɹ] and [l] in dialects of English in sandhi (e.g., $$$$). Though some have argued that the distribution of this segment can be viewed as 'natural' in the phonotactic sense of supplying a consonantal onset, the segmental content of the inserted consonant is an accident of history (Blevins 2004a, 252-53), as is generally the case with similar patterns of regular consonant epenthesis in the world's languages (Blevins to

appear). In addition, it is possible to find natural phonetically motivated sound patterns which, superficially, appear to be exceptional. These are sound patterns with highly restricted language-internal distributions, as in the case of the total assimilation of /l/ of the Arabic definite article /ʔal/ with a following coronal consonant (Blevins 2004a, 253-254). The fact that this assimilation is restricted to this particular clitic domain suggests, not that it is unnatural, but that the natural prosodic conditioning factors specific to this change are only found in this particular prosodic environment.[12] Evaluating naturalness, then, requires not only a detailed understanding of the segmental phonology of a language, but an understanding of its prosodic phonology as well.

In sum, a long tradition in phonology defines natural sound patterns as those grounded in articulatory and perceptual properties of speech. Natural sound patterns are those with plausible phonetic sources or explanations. No particular theory of grammar is associated with this definition. At the same time, in: the spirit of Baudouin, Ohala, and many others, hypotheses regarding the natural phonetic bases of sound patterns can be tested in the laboratory, and evaluated against the natural history of sound change as mapped out by the comparative method. With these strategies in mind, a guide to the most common and well documented instances of natural sound patterns are presented below.

2.2. A sampler of natural sound patterns

There is a wealth of literature on natural sound patterns and their phonetic basis. This section outlines a range of cases where evidence is more than anecdotal or hypothetical. Some sound patterns are written in a very specific form, others in general symbols, and others in prose. In an effort to condense information, some abbreviations are used. These are:

P	=	Primary perceptual basis	C	=	consonant
A	=	Primary articulatory basis	V	=	vowel
S	=	Synchronic	C_{vd}	=	plain voiced obstruent
D	=	Diachronic	C_{v}	=	plain voiced obstruents
Cf	=	Context-free			and implosives
Cs	=	Context-sensitive	$C\text{-}_{vd}$	=	voiceless obstruent
inc.	=	includes	N	=	nasal consonant

In some cases, where perception and articulation appear to play equal roles, a sound pattern is marked P/A. In order to keep the bibliographical section of this paper compact, only a few primary references are given for each sound pattern. These references contain phonetic explanations for the sound pattern in question, and in many cases, further references as well. In schematic notations, I use '>' as

[12] For arguments that a fixed prosodic hierarchy is in need of extension see Schiering et al. (2006).

a cover symbol for any alternation, and '<>' to show bidirectional alternations between sound types.

2.2.1. Alternations

Natural alternations include those that occur in synchronic grammars (S), and those that have occurred across time in regular sound change (D), or are present in synchronic variation. Below is a list of sound patterns/sound changes based on perceptual similarity (a-m) and apparent biases in the human perceptual system (n,o).

– Alternations with a primary perceptual basis (P)

a.	fricative > fricative, inc. θ > f, s > ʃ/_1	P, D, Cf	Ohala (1974), Blevins (2004a, 134-35)
b.	t > k	P, D, Cf	Blust (1990; 2004), Blevins (2004a, 122-25)
c.	flat > flat inc. pharyngealized, labialized, retroflex, velarized	P, D, Cf	Ohala (1974), Blevins (2004a, 136-37)
d.	aspiration <> nasalization, *aka* rhinoglottophilia	P, D, Cf	Blevins (2004a, 135-36)
e.	velar palatalization	P/A, S, D	Guion (1998)
f.	l > w	P, S, D	Ohala (1974)
g.	tonogenesis	P/A, D	Hombert et al. (1979)
h.	coronal rhotic > uvular rhotic	P, D	Engstrand et al. (to appear)
i.	final vowel shortening	P, D, S	Myers and Hanson (to appear)
j.	pre-vocoid vowel length neutralization	P, D, S	Myers and Hanson (2005)
k.	perceptual metathesis	P, D, S	Blevins and Garrett (1998; 2004)
l.	dissimilation	P, D, S	Blevins (2004a, 148-49)
m.	neutralization of release features when consonant is unreleased (inc. laryngeal and place features)	P, S, D	Steriade (1999), Blevins (2004a, Ch. 4 and Ch. 5)
n.	regressive assimilation of release features in CC clusters (inc. laryngeal and place features)	P, S, D	Ohala (1990), Steriade (2001), Blevins (2004a, Ch. 4 and Ch. 5)
o.	progressive assimilation of retroflexion in CC	P, S, D	Steriade (2001)

– Alternations with a primary articulatory basis (A)

There are far too many of these to list in a detailed way, so cover symbols are used wherever possible. Sound patterns in this category can be grouped into basic articulatory sources (coarticulation, mistiming, lenition, fortition) and aerodynamic factors. When sounds are coarticulated, the pronunciation of one has an effect on that of the other. A wide range of local and long-distance assimilatory sound patterns have their basis in coarticulation, including:

q.	local CV, VC, CC, VV assimilations	A, D, S	Hardcastle and Hewlett (1999), Recasens and Palares (2001)
r.	vowel harmony	A, D, S	Majors (1998), Harrison et al. (2002), Przezdziecki (2005)
s.	consonant harmony	A, D, S	Hansson (2001; 2004)

Segmental fusion can also occur under local assimilation, for example, the well studied development of tautosyllabic VN sequences into nasalized vowels, with loss of the nasal consonant, e.g., $$$$$ (Ohala 1975, Hajek 1997).

In the domain of tone, downdrift, sandhi rules and lexical tone assimilations have all been explained phonetically. Some key references are:

t.	tonal downdrift	A, D, S	Hombert (1974)
u.	tone sandhi	A, D, S	Shih (2005), Xu (2006)

Other alternation types with well-studied phonetic grounding are:

v.	compensatory lengthening	A, D, S	Kavitskaya (2002)
w.	positional neutralization	A, D, S	Barnes (2006)
x.	final obstruent devoicing	A, D, S	Blevins (2006a)
y.	consonant lenition	A, D, S	Kirchner (2004)
z.	consonant fortition	A, D, S	Kavitskaya (2005)

2.2.2. Phonotactics

All languages appear to have CV syllables, while many others have syllables that show regular syllable profiles which rise in sonority to the peak, and optionally fall in sonority thereafter. The study of the phonetic basis of recurrent phonotactic patterns is relatively young, but already has a range of concrete results. Redford et al. (2001) provide perceptual and articulatory explanations for preferred phonotactics, which are supported by the simulations of Oudeyer (2001). Wright (2004) presents an overview of segmental cue robustness, and argues that perceptual factors alone may favor common phonotactics, including alternating vowels and consonants, and syllables that respect the sonority scale. Gordon (2002; 2004) provides a phonetically driven account of syllable weight, showing how

tone and stress systems may have different phonetic requirements, and hence determine different weight systems.

The distribution of stress within words is the domain of metrical theory. A general question is to what extent the stress patterns of the world's languages have phonetic motivation, especially where rhythm is concerned. Hyman (1977, 44-45) suggests that many instances of word-stress are phonologizations of phrasal intonation patterns. Hayes (1995, 79-85) discusses the rhythmic basis of a universal foot inventory, while Trehub and Hannon (2006) summarize a wealth of studies on human perception of pitch and temporal patterns in music, suggesting a range of universals which, in: cases where they have been tested, appear to hold of speech as well.

A range of natural consonant-tone interactions, including those realized as phonotactics are described in Odden (2005). Kochetov (2002) provides a case study of the phonetically-based emergence of the phonotactics of contrastive palatalization.

2.2.3. Contrasts

There is a great deal more literature on unnatural contrasts than natural ones, for the simple reason that most contrasts made use of by the world's languages appear to be natural. Solé (1999) considers the naturalness of voiced trills (vs. unnatural nasal fricatives and nasal trills), and Maddieson (1984) discusses natural factors that play a role in common sound inventories and common (vs. uncommon) contrasts.

Systems of contrast seem to be central to an understanding of historical chain shifts, when two or more sound changes appear linked together, so that subsystems of contrast move together within the perceptual/acoustic space. The same is true of near-mergers, where a contrast appears to be neutralized, but maintains what appear to be significant phonetic differences. Both of these issues may be best tackled within exemplar models, as Yu (to appear) suggests for near-mergers in Cantonese tone.

3. Unnatural sound patterns

3.1. What are unnatural sound patterns?

On first thought, one might view unnatural sound patterns as any sound patterns that are not classified as natural in the sense defined above. However, the term 'unnatural' is used by many to express an opposition that is stronger than this, with a cline of naturalness, from the truly 'natural' at one extreme, to the truly 'unnatural' at the other. The most unnatural sound patterns are those that have all the distributional hallmarks of naturalness, being regular and exceptionless, but

lack phonetic grounding. A less extreme definition is adopted here: *Unnatural sound patterns are those with no plausible single phonetic source, origin, or explanation*. As with naturalness, unnaturalness, in: this sense, can be applied to synchronic contrasts, phonotactics, and alternations, as well as to sound change. In the realm of alternations, another term for unnatural sound patterns is 'crazy rules' (Bach and Harms 1972). In the domain of regular sound change, 'unusual' or 'bizarre' changes are highlighted in Blust (2005), where the basis of this classification is, again, the lack of clear phonetic grounding.

The most widely-studied source of unnatural sound patterns is likely analogy, as this term was used and understood in the 19th century and contrasted with natural 'mechanical' sound change (e.g. Paul 1880). Under analogy, a sound pattern may emerge from word-level changes based on form/meaning similarity relations between other sets of words. However, unnatural sound patterns have a variety of other sources, These include: 'rule inversion' where a historical sound change taking A > B in some environment is reinterpreted as a generalization on the distribution of A in the complement environment (Vennemann 1972); rule telescoping, where a sequence of historical sound changes A > B, B > C, etc. has a condensed form A > C in the grammar, with no evidence for intermediate stages (Hyman 1975, Ch. 5); accidental convergence of diachronic processes that result in regular sound patterns (Blevins 2004a, 69-70, 162-164); analogical morphophonology, where morphophonological alternations are reinterpreted as phonological ones (Garrett and Blevins, to appear); conscious or deliberate manipulation of linguistic symbols that result in regular sound change (Blust 2005, 264); and language contact (Blevins 2006a).

Providing empirical support for the classification of a sound pattern as 'unnatural' is more difficult than evidence for naturalness, since no amount of positive evidence will show that, for example, under certain conditions, [t]s *cannot be* perceived regularly as [k]s. In fact, though a regular context-free sound change **t* > *k* might at first glance seem unnatural, there is now evidence that it may be natural after all, because $$$$$ (Blevins 2004a, 122-125; Blust 2004). With instances of rule inversion, like the well-known English dialects that show intervocalic consonant epenthesis of [ɹ] in sandhi, as e.g. in $$$$$, the unnatural status of the rule is established by evidence from historical linguistics, typology and phonetics. These factors contribute to an understanding of this particular alternation by identifying an earlier process of coda /ɹ/-loss, high-lighting cross-linguistic correspondences with similar regular sound patterns with parallel histories, and by underscoring the lack of any phonetic evidence suggesting that speakers will tend to spontaneously produce [ɹ] or hear a non-existent [ɹ] in the contexts where the epenthetic consonant occurs (Blevins to appear). Similar multifaceted considerations are used in arguing for other sources of unnatural sound patterns. What all of these have in common is a starting point where the

sound pattern in question is one that is not known to follow from any natural phonetic principle.

In the domain of regular sound change, the great majority of changes show evidence of phonetic grounding. Nevertheless, exceptional cases are noted in the literature. Blevins (2004a, 164-167) mentions several unexplained regular sound changes, suggesting potential phonetic bases, while potential feedback loops in the course of acquisition may ultimately provide a source for the loss of final consonants in a range of Austronesian languages (Blevins 2004b). However, it has been argued that certain regular sound changes defy phonetic explanation. Blust (2005) classifies ten regular sound changes in Austronesian in this way. Since the majority of these changes involve unlikely single-step changes in the feature composition of segments (e.g. **b* > *-k-* in Berewan), there is always the possibility of intermediate steps which have been erased from the historic record (cf. the discussion of French **s* > zero in 2.1).[13] However, after considering a range of potential linguistic explanations for these sound changes, Blust (2005, 264) concludes that "speakers may sometimes engage in a conscious, arbitrary manipulation of linguistic symbols which produces systematic or semi-systematic results that resemble phonetically motivated sound change."[14] Section 2.2 lists a sample of these potentially unnatural regular sound changes.

The definition of unnatural sound patterns given above includes a large number of morphologically conditioned phonological alternations. Since word-internal morphological boundaries or domains are not, in: general, associated with specific phonetic properties, any word-internal morphological conditioning must be viewed as non-phonetic, and therefore 'unnatural'.

However, the same definition will classify many rare or unstable patterns as 'natural'. Consider, for example, the famous CCCCCC onset clusters of Georgian. Onset clusters of this kind are extremely rare in the world's languages, but are they 'unnatural'? As this term is defined above, they may not be, and, though uncommon, they claim a natural history as well (Blevins 2004a, 213-214). In the realm of contrast, the three-way contrast between oral, weakly nasalized, and fully nasalized, documented for Palantla Chinantec is also extremely rare, occurring only in this language, where it appears to be unstable. Here too, however, there is good reason to believe that the sound pattern has a natural history, and that its instability is also rooted in natural factors (Blevins 2004a, 202-204). In short, rare or unstable sound patterns can be natural, with rarity

[13] Blust (2005, 264) remarks: "No amount of speculation about possible intermediate steps is likely to provide a plausible phonetic motivation for more than a few of the changes considered here…".

[14] Deliberate speech modifications, including speech disguise and accomodation, do not typically have the form or content of the regular sound changes Blust assembles. Can a speaker simply decide that all medial /b/s will be pronounced as [k] (as required for Berewan), perform this operation without exception, and then be correctly imitated by others? This seems to be what Blust is suggesting.

following from the uncommon convergence of various phonetic factors, and instability due to independent natural phonetic factors.

A final topic of general interest is the role of purported *unnatural* sound patterns in modern approaches to markedness. The dissociation of markedness and naturalness noted in section 1 has lead to a somewhat strange logic in recent Optimality studies. The argument goes essentially as follows. Universal markedness constraints or principles must be recognized as components of phonological grammars because there are many *unnatural* sound patterns in the world's languages that demand explanation. For example, DeLacy (2006, 5) claims that the output of regular epenthesis rules is always a coronal or glottal, and never a labial or dorsal. Glottals may be natural outcomes of epenthesis, because $$$$ (cf. Blevins to appear), but there is no *natural* explanation for why coronals should be preferred over dorsals and labials. This is the justification of synchronic markedness constraints, in: this case, one favoring coronal place over dorsal and labial. In this approach, markedness becomes the means of expression of *unnatural* sound patterns in contrast to its original structuralist and generative use. While the theory-internal logic may be sound, the empirical basis is not. Restricting consonant epenthesis to coronals and glottals is indeed unnatural, and no such restriction is evident in the natural history of sound patterns (Blust 1994; Vaux 2002; Mortensen 2004; Blevins to appear).[15]

3.2. A sampler of unnatural sound patterns

Since unnatural sound patterns are defined negatively, by the lack of phonetic grounding, they will be more difficult to identify than natural sound patterns. Nevertheless, the examples below should give the reader a good feel for the types of sound patterns which, to date, appear to have no such motivation. In 3.2.1 exemplification is limited to extreme cases of unnatural rules – those sound patterns that have all the distributional hallmarks of naturalness, being regular and exceptionless, but which lack phonetic grounding. Since these unnatural sound patterns are specific to particular languages or families, language and family information is provided as well.

A special note is in order regarding the sound change in 3.2.1 h. which could be viewed as 'natural' if open syllables are natural (in contrast to closed ones). Blevins (2004b) notes, however, that the sound change in h. is one which only occurs (in non-contact situations) when the output is a language with uni-

[15] DeLacy (2006, 19), however, is not concerned with the natural history of sound patterns, or naturalness in the sense defined here: "speech-related asymmetries that are caused by factors external to I-language are not relevant to the theoretical proposals made here". Phonetic factors are included in this notion of 'external', and regular sound change is excluded from the empirical database.

formly open syllables across the word. This is a case, then, where the feedback loop discussed in 2.1 may play an important role in language change.

In the set of synchronic alternations referred to in 3.2.1 u.-z. below, the class of sound referred to as the target or context of the alternation is a non-natural (or unnatural) class. In these examples, the general alternation type is given together with the language in the middle column. For more on the widespread existence of non-natural classes in synchronic phonology, see Mielke (2004).

3.2.1 Alternations

a.	w/j > -p	Drehet, Levei	D,Cs	Blust (2005)
b.	w/b > c-, -nc-	Sundanese	D, Cs	Blust (2005)
c.	dr > k^h	Drehet	D, Cf	Blust (2005)
d.	b > -k-	Berewan	D, Cs	Blust (2005)
e.	t > k	Oceanic	D, Cf	Blust (1990)[16]
f.	Ø > j / [_a	Oceanic	D, Cs	Blust (1990)
g.	C > Ø /[_	Pama-Nyungan	D, Cs	Blevins (2001)
h.	C > Ø / _]	Oceanic	D, Cs	Blevins (2004b)
i.	C > Ø / _]	Cajun English	D, Cs	Blevins (2006b)
j.	t,t^h,d > s/_m	Ancient Greek	S, Cs	Paul (1880) Garrett & Blevins (to appear)
k.	p > s/_i	Bantu	S, Cs	Hyman (1975, 174-175)
l.	i > u/d_	Kashaya	S, Cs	Buckley (2000)
m.	n > /_i,j	E. Ojibwe	S, Cs	Buckley (2000)
n.	M > L/_ C_{vd}	Zina Kotoko	S, Cs	Odden (2005)
o.	M > L/C_v_	Zina Kotoko	S, Cs	Odden (2005)
p.	Ø >dz/V_i	Chamorro	S, Cs	Blevins (to appear)
q.	Ø > ŋ /V_V	Uradhi	S, Cs	Blevins (to appear)
r.	h > l /{V+$_{bk}$,C}_V	Wiyot	S, Cs	Blevins & Garrett (to appear)
s.	C-$_{vd}$ > C_{vd}/ _]	Lezgian	S, Cs	Yu (2004)
t.	antigemination[17]	Tonkawa, Tunisian Arabic, etc.	S, Cs	Blevins (2005)
u.	/t,k,s,□,h/ but not /p/	Japanese, target of voicing	S, Cs	Mielke (2004, 156-157)

[16] This sound change is also listed as a potentially natural one in 2.2. See Blevins (2004a, 122-125) and Blust (2004) for further details.

[17] Antigemination is the sound pattern so-named by McCarthy (1986) in which a regular syncope rule is blocked just in case it results in adjacent identical consonants.

v.	/v s g/, but not /b/, /d/, /x/, etc.,	Evenki, target of post-nasal nasalization	S, Cs	Mielke (2004, 165-166)
w.	_/t g s j/, but not other Cs	River W. Tarangan, /m/ regressive place-assimilation	S, Cs	Mielke (2004, 166-168)
x.	/_{□ s^w n}, but not other Cs	Thompson, /t/-deletion	S, Cs	Mielke (2004, 168-169)
y.	{n n' □ h}_, but not other Cs	Thompson, /t/-deletion	S, Cs	Mielke (2004, 168-169)
z.	/_ {C-$_{vd}$,N}, but not other Cs	Pero stop assimilation	S, Cs	Mielke (2004, 183-184)

3.2.2. Phonotactics

In the realm of phonotactics, no widely accepted notion of 'natural' vs. 'unnatural' exists in the literature. Assume, following the discussion in 2.2.2, that one adopts the results of Redford et al. (2001), Oudeyer (2001), and Wright (2004) on the perceptual and articulatory basis of preferred phonotactics and syllable types where major class features and sonority are involved. It then follows that languages with long consonant clusters (e.g. Georgian, Bella Coola), syllabic obstruents (Tashylhit Berber), and syllable-internal sonority violations (Georgian, Polish, English) would all be instances of languages with decidedly 'unnatural' phonotactics. Since languages of this type are not unusual (Blevins 1995), and phonotactics of this type can be quite stable (Blevins 2006b), this constitutes further evidence that unnatural patterns are common features of synchronic grammars.

The preference for CV syllables may be related to a cross-linguistic tendency for VCV to be syllabified as V.CV. Languages with seemingly unnatural syllabification patterns include Oykangand where intervocalic single Cs and consonant clusters are syllabified as codas rather than onsets (Blevins 2004a, 69-70, 234-245).

3.2.3. Contrasts

As mentioned in 2.2.3, there is a great deal more literature on unnatural contrasts than natural ones, though unnatural contrasts or systems are those which are typically unattested in the world's languages. For example, there is no language which has only voiced stops and voiced implosive stops: the occurrence of phonologically voiced stops seems to imply voiceless stops as well. **Is this an implicational universal?** Most of the contrasts made use of in the world's languages appear to be natural in the sense that they can arise in natural ways, and they do not push the articulatory or perceptual limits of human speech. A few exceptions to this are noted in Blevins (2004a, Ch. 7) where certain rare

contrasts are discussed. These include the rare three-way nasalization contrast in Palantla Chinantec vowels, mentioned earlier, as well as three-way length contrasts in Estonian, Saami, and Dinka. In these cases, phonological contrast does appear to push the perceptual envelope, with neutralization occurring or expected as soon as these features lose their unique morphologically contrastive function. **Please add example**

4. Naturalness and synchronic grammars; conclusions

All languages appear to have natural and unnatural sound patterns. The simplest and most widely accepted explanation for this is a historical one. Though natural synchronic sound patterns can evolve as true reflections of natural phonetically based sound change, the same sound patterns can be rendered unnatural by subsequent natural changes, inversions, analogical changes, lexicalization, and language contact. Given that we understand the natural phonetic basis of such patterns, is there any reason to believe that identical or similar principles are part of phonological grammars, or that phonological grammars instantiate preferences for 'natural' sound patterns?

Anderson (1981, 497) answers in the negative. Phonetic explanations are explored in phonology precisely "to determine what sorts of facts the linguistic system proper is not responsible for". Similar conclusions can be found in Ohala (1974; 1981), Lass (1975; 1980; 1984) and Hyman (2001). All of these authors highlight that the explanations of sound patterns by reference to naturalness is a distinct enterprise from describing aspects of grammars. Further, where attempts are made to encode naturalness in the grammar, problems inevitably arise. In reviewing the differences between the simple definition of naturalness proposed in 2.1 and the extended definitions made use of in Natural Phonology the same point is clear. Natural Phonology fails, not because naturalness is irrelevant to explaining sound patterns, but because naturalness is simply irrelevant to grammatical description and analysis (Hellberg 1978). Natural and unnatural sound patterns can both be regular and exceptionless, and naturalness may also be dissociated from universality, as suggested in 2.1.

Despite these seeming failures, certain schools of Optimality Theory maintain the position that naturalness is a part of synchronic grammars. Kager (1999, 11) states that phonological markedness constraints in OT are universal, and that universality should ideally be established by showing that these constraints are "phonetically grounded in some property of articulation or perception". While this position has been abandoned by most practitioners, there are still proponents of phonetic naturalness in OT grammars. Hayes and Steriade (2004, 3) do not define markedness constraints as innate and universal, but do view phonetic knowledge as the "source of markedness constraints as components of grammar" (ibid., 1). Continued challenges to this position have forced

proponents of markedness to test their proposals with new experimental methods. One line of research attempts to defend grammar-internal expressions of markedness by showing that natural rules are easier to learn than unnatural ones.

If it is the case that all languages show evidence of natural and unnatural sound patterns, then surely both types of patterns are learnable in the course of language acquisition. But are natural patterns easier to learn than unnatural ones? This is the claim of, e.g., Tesar and Smolensky (2000).[18] In order to test this hypothesis a range of experiments have been carried out. Results in this area are difficult to evaluate, as they often use artificial languages, and may be carried out on adults, as opposed to children in the relevant stages of language acquisition. An additional problem is very general: if learners do indeed learn a natural pattern more easily than an unnatural one, how can we be sure this is due to phonological knowledge, as opposed to more general cognitive strategies?[19] In one of the few studies carried out on infants, Seidle and Buckley (2005) exposed 9-month old infants to phonetically grounded sound patterns as well as ungrounded ones, with one experiment focused on consonant manner and the other on place of articulation. In both experiments infants showed no learning preference for the natural pattern over the unnatural one, suggesting that, at this age, they have no clear bias towards natural sound patterns.

For those interested in understanding sound patterns, naturalness plays a clear and fundamental role. For those interested in understanding grammars, the natural or unnatural status of a sound pattern may be of little or no import, with naturalness independent of grammatical description. Is this independence consistent with recent work on the form and content of phonological grammars? Yes, it most certainly is. First, there is a growing literature on the emergent properties of many aspects of phonological systems, from distinctive features (Mielke 2004), segment inventories (De Boer 2001), and regularities across the lexicon (Wedel to appear), to general phonological architectures that decompose words into syllables, segments and features (Oudeyer 2006). Languages are self-organizing systems, and modeling them in this way frees grammars from the burden of universality. Second, there is mounting evidence that the majority of phonological knowledge is learned and language-specific, and that this learning begins to take place well before children learn to speak (Kuhl et al. 1992, Saffran et al. 1996, Kuhl 2000; 2004). If sound patterns, whether natural or unnatural, are learned aspects of grammar, what is gained by importing notions of 'naturalness' into the grammar? Finally, there is experimental data showing that phonological knowledge is phonetically detailed, and also includes probabilistic knowledge of

[18] Their proposal is actually that unmarked sound patterns are easier to learn than marked ones, where OT markedness constraints are involved. As the authors have different notions of the extent to which this may be universal and/or phonetically grounded, their definition of 'naturalness' may not overlap significantly with the one adopted here.

[19] See Trehub and Hannon (2006) for arguments that infant music perception is grounded in domain-general (non-music-specific) cognitive mechanisms.

sound sequences across the lexicon, syntactic probabilities, social characteristics of speakers, and much more (Johnson 1997, Pierrehumbert 2000; 2003, Ernestus and Baayen 2003, Gahl and Garnsey 2006). If phonotactic well-formedness judgments are graded according to properties of the lexicon, how can importing a notion of naturalness improve a grammatical description?

In sum, many common and recurrent sound patterns can be explained in terms of the way humans articulate and perceive speech. The study of naturalness through the ages has deepened our understanding of sound patterns, and continues to do so, especially where it is properly segregated from grammatical description and analysis.

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