Morphologically conditioned phonological alternations

Arto Anttila
Boston University
and
National University of Singapore

Abstract

Alternations that are partly phonologically, partly morphologically conditioned are a central problem in phonological theory. In Optimality Theory, two types of solutions have been proposed: morphologically specialized phonological constraints (interface constraints) and different constraint rankings for different morphological categories (cophonologies). This paper presents empirical evidence that distinguishes between these two hypotheses. Stem-final vowel alternations in Finnish are governed by a mixed set of conditions that range from purely phonological to morphological and lexical, from iron-clad exceptionless regularities to quantitative tendencies. Using a standard dictionary as the data base, we show that phonological conditioning plays the dominant role, but in cases where phonology underdetermines the output, morphological conditioning may emerge. We then show that partial ordering of constraints, commonly used to model variation, extends to morphological conditioning as well. The partial ordering model is a restrictive version of the cophonology model which is thus supported.

1. Introduction

There are two kinds of phonological alternations: those that are purely phonologically conditioned and those that are conditioned by an amalgam of phonological, morphological and lexical information.[1] Alternations of the second type raise an important general question: how exactly do phonological, morphological and lexical information interact in the grammar?

This question has a long history of diverse answers. At one extreme, we find those post-Bloomfieldian structuralists who essentially denied any interaction by maintaining a sharp conceptual distinction between phonemics and morphophonemics (Harris 1951). The diametrically opposite approach was taken in SPE (Chomsky and Halle 1968) where a phonological rule A $\rightarrow$ B / C_D could freely refer to phonological, morphological, syntactic and lexical information in its context conditions. An intermediary position was subsequently taken in the various developments of Lexical Phonology and Morphology (Kiparsky 1982, Mohanan 1986) where phonological rules are divided into two types: those that interact with morphology in the lexicon (lexical rules) and those that do not (postlexical rules). Both lexical and postlexical rules are genuine phonological rules. Their various differences arise from the way they are embedded in the grammar.

In Optimality Theory (Prince and Smolensky 1993), morphologically conditioned phonology has been approached in two principal ways. The direct way is to posit INTERFACE CONSTRAINTS, that is, faithfulness, markedness and alignment constraints parameterized to apply to designated morphological categories, e.g. roots vs. affixes (McCarthy and Prince 1995, Urbanczyk

[1]This work has benefited from presentations at WCCFL XVII at the University of British Columbia (February 1998), MIT Phonology Circle (March 1998), the University of Massachusetts at Amherst Linguistics Colloquium (November 1998) and the University of Hong Kong (June 1999). I thank Edward Flemming, Vivienne Fong, Heli Harrikari, Tarja Heinonen, Catherine Howell, Yoonjung Kang, Michael Kenstowicz, Brett Kessler, John Kingston, Paul Kiparsky, James Myers, K.P. Mohanan, Carol Neidle, Cheryl Zoll and three anonymous reviewers for comments and Brett Kessler for the Perl code for doing constraint permutations. I also thank the Research Institute for the Languages of Finland for the permission to use the electronic version of *Nykysuomen sanakirja* [Dictionary of Modern Finnish] and the Centre for Advanced Studies at the National University of Singapore for an excellent working environment in the summer of 1999. This research was partly supported by a National University of Singapore Faculty of Arts and Social Sciences Postdoctoral Fellowship. All errors are my own.

The following abbreviation are used: AG = agent, INE = inessive, INF = infinitive, PAST = past tense, PCP = participle, PL = plural, PRES = present tense, COND = conditional.

1996, Beckman 1998, Alderete 1999), nouns vs. other word classes (Smith 1997), heads vs. dependents (Revithiadou 1999), words vs. phrases (Hayes to appear), lexical strata (Fukazawa et al. to appear), affix classes (Benua 1995, 1998), and even individual morphemes/lexemes (Hammond 1995, Myers 1999, Russell 1995, 1999). As a representative example, consider Smith's (1997) Noun Faithfulness constraints. Ranking (1) describes a language where accents shift to an unmarked position dictated by the markedness constraint $\mathcal{M}$(accent-location), except in nouns where the accent remains faithful to its underlying position due to $\mathcal{F}_{noun}$(accent-location).

(1) Interface constraints:

$$\mathcal{F}_{noun}(\text{accent-location}) \gg \mathcal{M}(\text{accent-location}) \gg \mathcal{F}(\text{accent-location})$$

The alternative is to keep phonological constraints purely phonological, but posit a range of distinct COPHONOLOGIES, that is, different constraint rankings for different morphological categories (McCarthy and Prince 1993, Itô and Mester 1995a, 1995b, 1998, Orgun 1996, Inkelas 1998, 1999, Kiparsky to appear). Returning to our example, we could propose that nouns subscribe to cophonology (2a) and all other words to cophonology (2b).

(2) Cophonologies:

a. $\mathcal{F}(\text{accent-location}) \gg \mathcal{M}(\text{accent-location})$ (nouns)
b. $\mathcal{M}(\text{accent-location}) \gg \mathcal{F}(\text{accent-location})$ (other words)

These two approaches are conceptually quite distinct. However, it is often possible to analyze the same phenomenon either way. This has been recognized in the literature (e.g. Itô and Mester 1998), but few empirical arguments have been advanced for or against either theoretical option. In this study, we will examine stem-final vowel alternations in Finnish with the specific purpose of finding empirical evidence that could distinguish between these two hypotheses. We will examine these alternations in their phonological, morphological, lexical, quantitative and diachronic aspects in order to accumulate sufficiently detailed empirical evidence for the argument. We first describe the basic phonological and morphological generalizations and then derive these generalizations by exploiting an inherent property of optimality-theoretic grammars: PARTIAL ORDERING. The partial ordering model is a restrictive version of the cophonology model which is thus supported.

The paper is constructed as follows. Section 2 gives an overview of the basic facts. Section 3 lays out the phonological, morphological and lexical generalizations. Section 4 presents an analysis based on partially ordered grammars. Section 5 shows why the facts would be problematic for an interface constraint approach and why partial ordering is necessary. Section 6 concludes the paper. Unless otherwise indicated, the data are based on an electronic version of *Nykysuomen sanakirja* [Dictionary of Modern Finnish] (Sadeniemi 1973) courtesy of the Research Institute for the Languages of Finland (`http://www.domlang.fi`).

2. Finnish vowel alternations

Finnish has a rich array of phonological alternations that affect stem-final vowels in connection with suffixation. This paper deals with two alternations that affect stem-final low vowels before a suffixal /i/: the low vowel either MUTATES to a mid vowel or DELETES completely, subject to an intricate set of conditions that are the subject matter of this paper.

In a great number of cases, mutation and deletion are purely phonologically conditioned (Penttilä 1963:140-142, F. Karlsson 1982:337-342). This is illustrated in (3) and (4) using informal rules.

(3) a → o / {i, a, e} . __ -i-$_{\{pl,past\}}$

/kana-i-ssa/	kano-i-ssa	'hen-PL-INE'
/balleriina-i-ssa/	balleriino-i-ssa	'ballerina-PL-INE'
/metka-i-ssa/	metko-i-ssa	'funny-PL-INE'
/pala-i/	palo-i	'burn-PAST'

(4) a → ∅ / {u, o} . __ -i-$_{\{pl,past\}}$

/muna-i-ssa/	mun-i-ssa	'egg-PL-INE'
/synagooga-i-ssa/	synagoog-i-ssa	'synagogue-PL-INE'
/ruma-i-ssa/	rum-i-ssa	'ugly-PL-INE'
/otta-i/	ott-i	'take-PAST'

The choice between mutation and deletion is determined by the left hand context of the alternation. The low vowel /a/ mutates to a rounded mid vowel *o* if the nucleus of the preceding syllable is unrounded, as shown in (3). The

resulting diphthong *oi* (e.g. *ka.nois.sa*) is phonologically a single vowel or a tautosyllabic vowel sequence, depending on the environment (Keyser and Kiparsky 1984:22-25). For our purposes, the difference will not matter. The low vowel /a/ deletes if the nucleus of the preceding syllable is rounded, as shown in (4). The right hand context requires the presence of /-i-/ which is either the plural or past tense morpheme.

These alternations are regular and productive. They occur in literally thousands of stems, including recent loans such as *balleriina* 'ballerina' and *synagooga* 'synagogue'. Not only do they apply to nouns, but also to adjectives and verbs, as the examples show. However, there is a curious restriction: the rules apply regularly only in nonderived stems with an even number of syllables. This reveals two fundamental facts: the rules are sensitive to morphology and they count syllables.

Let us now consider a series of examples showing how the rules fail. The stems in (5) are nonderived, but trisyllabic.

(5)	a.	/tavara-i-ssa/	tavaro-i-ssa	'thing-PL-INE'
	b.	/jumala-i-ssa/	jumal-i-ssa	'God-PL-INE'
	c.	/itara-i-ssa/	itaroi-ssa∼itar-i-ssa	'stingy-PL-INE'

The first stem mutates, the second stem deletes, and the third stem varies freely between mutation and deletion, for no obvious phonological reason. *Nykysuomen sanakirja* describes this state of affairs by assigning the stems to different DECLENSIONS: *tavara* belongs to declension 15, *jumala* to declension 53, and *itara* to declension 12. Declension numbers are mnemonic labels that associate a given stem with a specific alternation behavior, including the appropriate mutation/deletion pattern.

The rules also fail in derived stems. The three derivational suffixes in (6) are all different. Just as in nonderived stems, a following /-i-/ is required to trigger the alternation.

(6)			i . __	a . __	o . __
	a.	/-la/ 'place'	kahvi-**lo**-i-ssa	kana-**lo**-i-ssa	hoito-**lo**-i-ssa
	b.	/-ja/ 'actor'	tutki-**jo**-i-ssa	anta-**j**-i-ssa	hiero-**j**-i-ssa
	c.	/-va/ 'PRES.PCP'	tutki-**v**-i-ssa	anta-**v**-i-ssa	hiero-**v**-i-ssa

kahvi-la 'café', *kana-la* 'chicken shed', *hoito-la* 'sanatorium'; *tutki-ja* 'researcher', *anta-ja* 'giver', *hiero-ja* 'masseur'; *tutki-va* 'researching', *anta-va* 'giving', *hiero-va* 'massaging'

The suffix *-la* 'place' mutates across the board. The suffix *-ja* 'actor' deletes after all vowels, except after /i/ where we find mutation. Finally, the suffix *-va* 'present participle' deletes across the board. Again, the dictionary describes this diversity in terms of declensions. However, as we shall see shortly, the number of possible patterns is limited and these patterns can be derived from general phonological principles.

Finally, we find straightforward lexical exceptions:

(7)	a.	/taitta-i/	taitto-i(∼taitt-i)	'break-PAST'
	b.	/suola-i-ssa/	suolo-i-ssa	'salt-PL-INE'

Example (7a) shows unexpected variable deletion after an unrounded vowel. This marginal pattern is found in approximately 35 verb stems (F. Karlsson 1982:339-40). Example (7b) shows the reverse type of exception: unexpected mutation after a rounded vowel. This pattern only occurs in a handful of stems, all of which have /u/ as the first syllable nucleus.[2]

Finnish vowel mutation and deletion are fairly typical morphophonemic alternations. In some stems, they are purely phonological and fully predictable, in others they are phonologically erratic and involve morphological and lexical conditions. Our goal is to figure out how the system works: why are the rules phonologically regular in some environments, but irregular in others? We start by examining one of the clearest areas where phonology breaks down: trisyllabic stems.

3. Trisyllabic stems

3.1. The preceding vowel effect

The following table divides nonderived trisyllabic nominal stems into three types: mutation stems, variable stems and deletion stems, based on the

[2]One popular explanation for *suolo-i-ssa* 'in the salts' is homonymy avoidance: the expected *suol-i-ssa* happens to mean 'in the intestines' (from *suoli*). Unfortunately, the explanation only works in this very case. Consider *korva* 'ear' *korv-i-ssa* 'in the ears', also 'in the wildernesses' (from *korpi*) and *tukka* 'hair' *tuk-i-ssa* 'in the hairs', also 'in the log' (from *tukki*), where homonymy is not avoided.

For completeness, we note that *Nykysuomen sanakirja* lists one exceptionally mutating disyllabic noun where the first syllable nucleus is /o/: *routa* 'frost in the ground', implying that the correct form is *roudo-i-ssa* which I find totally impossible. This may be a typographical error.

declensional information given in *Nykysuomen sanakirja*. The stems are classified by the penultimate nucleus. The first entry in each cell gives the number of stems instantiating the mutation, variation, and deletion patterns. The second entry gives the percentage of each cell relative to the total number of cases.

(8) M = mutation, ∼ = variation, D = deletion

	i . __	a . __	e . __	u . __	o . __	Total:
M	306 99.4%	272 66.8%	58 20.6%	186 75.9%	17 28.3%	839
∼	2 0.6%	85 20.9%	183 64.9%	49 20.0%	15 25%	334
D	– –	50 12.3%	41 14.5%	10 4.1%	28 46.7%	127
Total:	308 100%	407 100%	282 100%	245 100%	60 100%	1,302

It is immediately obvious that no categorical phonological rules can be written: both mutation and deletion are allowed after every vowel. However, there are significant quantitative differences. We find the highest mutation rate with /i/ and the highest deletion rate with /o/. The five vowels seem to settle along the following hierarchy in terms of how strongly they prefer mutation and deletion.

(9) Vowel Hierarchy (from mutation to deletion):

/i/ > /a,e,u/ > /o/

The split between /i/-environments and /o/-environments emerges clearly in recent loanwords. After /i/ deletion is systematically impossible. After /o/ deletion is possible and typically preferred.

(10) a. /angiina/ angiino-i-ssa 'angina'
/gorilla/ gorillo-i-ssa 'gorilla'
/vagina/ vagino-i-ssa 'vagina'

b. /triljoona/ triljoon-i-ssa 'trillion'
/madonna/ madonn-i-ssa 'madonna'
/gallona/ gallon-i-ssa 'gallon'

The shapes of suffixal declensions are also constrained by the vowel hierarchy. Some suffixes completely ignore the vowel and either mutate or delete across the board. However, the suffix *-ja* 'actor' shows a split pattern:

(11)

		i . _	a . _	e . _	u . _	o . _
a.	*-la* 'place'	M	M	M	M	M
b.	*-ja*$_1$ 'actor'	M	M∼D	M∼D	M∼D	M∼D,D
c.	*-ja*$_2$ 'actor'	M	D	D	D	D
d.	*-va* 'PRES.PCP'	D	D	D	D	D

The suffix *-ja*$_1$ is the variant described in *Nykysuomen sanakirja*. It shows categorical mutation after /i/ and free variation elsewhere, except for some cases of categorical deletion after /o/. *-ja*$_2$ is the currently used variant (G. Karlsson 1978:92): it shows categorical mutation after /i/ and deletion elsewhere. In both cases, the declension respects the vowel hierarchy.

Three questions arise: (i) Why are even-numbered and odd-numbered stems different; (ii) Why are different suffixes different; (iii) Why do the vowels appear in this particular order? Before answering these questions, we turn to another phonological condition that plays a role in the mutation/deletion choice: the quality of the preceding consonant.

3.2. The preceding consonant effect

The consonant immediately preceding the alternating vowel also plays a role in the mutation/deletion preferences. This possibility was first suggested to me by Yoonjung Kang (p.c.).

(12) Labial = /m,p,b,v,f/, coronal = /t,d,s,n,r,l,j/ or no consonant (hiatus), dorsal = /k,g/.

	labial	coronal	dorsal	Total:
M	15 9.1%	402 56.5%	422 99.1%	839
∼	34 20.6%	297 41.8%	3 0.7%	334
D	116 70.3%	12 1.7%	1 0.2%	129
Total:	165 100%	711 100%	426 100%	1,302

It is again immediately obvious that no categorical phonological rules can be written. Both mutation and deletion are allowed after every consonant. However, the quantitative pattern is strikingly clear: stems with a labial consonant favor deletion, stems with a dorsal consonant favor mutation, and coronals fall somewhere in between. Some typical examples are listed in (13).

(13)	a.	/pisa<u>m</u>a/	*pisamo-i-ssa/pisam-i-ssa	'freckle-PL-INE'
	b.	/ome<u>n</u>a/	omeno-i-ssa∼omen-i-ssa	'apple-PL-INE'
	c.	/sila<u>kk</u>a/	silako-i-ssa/*silak-i-ssa	'Baltic herring-PL-INE'

Just like vowels, consonants form a hierarchy with respect to mutation/deletion preferences:

(14) Consonant Hierarchy (from mutation to deletion):

/k,g/ > /t,d,s,n,r,l,j/ > /m,p,b,v,f/

The consonant hierarchy emerges particularly clearly in derivational suffixes. (15) is an exhaustive list of /a/-final derivational suffixes based on F. Karlsson 1982:250-257,265-6.

(15)	labial	/-ma/	'nominalizer'	D	sattu-ma	'event'
		/-ma/	'AG.PCP'	D	otta-ma	'taken'
		/-mpa/	'comparative'	D	vanhe-mpa	'older'
		/-va/	'PRES.PCP'	D	otta-va	'taking'
		/-lma/	(lexicalized)	D	kude-lma	'knitwork'
		/-rva/	(lexicalized)	D	pune-rva	'reddish'
	coronal	/-isa/	'-ful'	D	rauha-isa	'peaceful'
		/-ea/$_2$	(lexicalized)	D	kukk-ea	'flowery'
		/-ja/	'actor'	M∼D	kanta-ja	'carrier'
		/-ea/$_1$	(lexicalized)	M∼D	kukk-ea	'flowery'
		/-la/	'place'	M	kahvi-la	'café'
		/-nta/	'nominalizer'	M	ota-nta	'sampling'
		/-na/	'nominalizer'	M	kirku-na	'screaming'
		/-usta/	(lexicalized)	M	hiil-usta	'embers'
	dorsal	/-ska/	'female'	M	kapteen-ska	'captain's wife'
		/-kka/	(lexicalized)	M	silmu-kka	'loop'
		/-kka/	(lexicalized)	M	kuula-kka	'clear'

Suffixes with a labial consonant undergo categorical deletion after all vowels; suffixes with a coronal consonant or hiatus mutate, delete or vary; suffixes with a dorsal consonant undergo categorical mutation after all vowels.

3.3. The phonological generalization

Rounded vowels and labial consonants favor deletion, high vowels and dorsal consonants favor mutation. This observation can be naturally intepreted as evidence for DISSIMILATION, which is one of the many possibilities considered by Finnish historical phonologists (see e.g. Itkonen 1942 and Wiik 1984). Following the articulator-based feature theory (Sagey 1986, Halle 1992), we assume that rounded vowels and labial consonants share the feature [round] and high vowels and dorsal consonants share the feature [high]. The dissimilation hypothesis can now be stated as a special case of the Obligatory Contour Principle (Leben 1973). We put on hold the precise definition of adjacency for now.

(16) The phonological generalization:

a. Avoid adjacent [round] segments (OCP[round]).
b. Avoid adjacent [high] segments (OCP[high]).

The role of the OCP here is to block two otherwise regular sound changes. Thus, since mutation ($a \rightarrow o$) creates a rounded vowel, it is avoided after [round] segments. This is shown in (17a). Since deletion disposes of a completely, the plural suffix i, which is a [high] vowel, ends up being adjacent to the consonant. For this reason, deletion is avoided after [high] segments. This is shown in (17b).

(17)	a.	/muna/	mun-i-ssa/*m<u>u</u><u>n</u><u>o</u>-i-ssa	'egg-PL-INE'
		/pisama/	pisam-i-ssa/*pisa<u>mo</u>-i-ssa	'freckle-PL-INE'
	b.	/tila/	tilo-i-ssa/*t<u>i</u><u>l</u>-<u>i</u>-ssä	'space-PL-INE'
		/silakka/	silako-i-ssa/*sila<u>k</u>-<u>i</u>-ssa	'Baltic herring-PL-INE'

Mohanan (1993:86–7) points out that two nonabsolute phonological regularities can together yield an absolute regularity. More specifically, Frisch et al. 1997 have convincingly shown that place-OCP effects are cumulative in Arabic. Given this, we might expect deletion to be virtually categorical in stems like *glaukooma* 'glaucoma' where both the vowel and consonant are [round], and mutation to be virtually categorical in stems like *mansikka* 'strawberry' where both are [high]. This is indeed what we find. Table (18) displays the 12 logically possible combinations of vowel (high, round, both, neither) and consonant (high, round, neither) with the attested outcomes.

(18) The combined vowel-consonant effect:

	V	C	M	∼	D	Total	Example
1.	high	high	100%	–	–	140	mansikka
2.	high,round	high	100%	–	–	89	puolukka
3.	–	high	100%	–	–	187	silakka
4.	high	–	99%	1%	–	162	karsina
5.	high	round	83%	17%	–	6	Fatima
6.	high,round	–	68%	32%	–	143	ikkuna
7.	round	high	60%	30%	10%	10	mahorkka
8.	–	–	36%	64%	0%	373	omena
9.	round	–	33%	33%	33%	33	gallona
10.	–	round	8%	22%	70%	129	orava
11.	high,round	round	–	23%	77%	13	hekuma
12.	round	round	–	6%	94%	17	glaukooma
						1,302	

mansikka 'strawberry', *puolukka* 'lingonberry', *silakka* 'Baltic herring', *karsina* 'coop', *Fatima* 'Fatima', *ikkuna* 'window', *mahorkka* 'Russian tobacco', *omena* 'apple', *gallona* 'gallon', *orava* 'squirrel', *hekuma* 'lust', *glaukooma* 'glaucoma'

Table (18) reveals two environments where mutation is virtually categorical: (i) if the consonant is [high], except if the vowel is [round]; (ii) if the vowel is [high], except if the consonant is [round]. We also note that the highest concentration of variable stems (64%) is found precisely in the neutral environment, i.e. where the vowel and the consonant are neither [high] nor [round].

If we keep the vowel constant and vary the consonant, we can see the consonant effect clearly. This is shown in (19).

(19)

	V	C	M	∼	D	Total	Example
a.	high	high	100%	–	–	140	mansikka
	high	–	99%	1%	–	162	karsina
	high	round	83%	17%	–	6	Fatima
b.	high,round	high	100%	–	–	89	puolukka
	high,round	–	68%	32%	–	143	ikkuna
	high,round	round	–	23%	77%	13	hekuma
c.	–	high	100%	–	–	187	silakka
	–	–	36%	64%	0%	373	omena
	–	round	8%	22%	70%	129	orava
d.	round	high	60%	30%	10%	10	mahorkka
	round	–	33%	33%	33%	33	gallona
	round	round	–	6%	94%	17	glaukooma

We find the highest mutation rates with [high] consonants and the highest deletion rates with [round] consonants. The neutral coronal consonants fall somewhere in between. The consonant hierarchy holds without exception in all vocalic environments.

If we keep the consonant constant and vary the vowel, we can see the vowel effect clearly. This is shown in (20).

(20)

	V	C	M	∼	D	Total	Example
a.	high	high	100%	–	–	140	mansikka
	–	high	100%	–	–	187	silakka
	high,round	high	100%	–	–	89	puolukka
	round	high	60%	30%	10%	10	mahorkka
b.	high	–	99%	1%	–	162	karsina
	–	–	36%	64%	0%	373	omena
	high,round	–	68%	32%	–	143	ikkuna
	round	–	33%	33%	33%	33	gallona
c.	high	round	83%	17%	–	6	Fatima
	–	round	8%	22%	70%	129	orava
	high,round	round	–	23%	77%	13	hekuma
	round	round	–	6%	94%	17	glaukooma

We find the highest mutation rates with [high] vowels, and the highest deletion rates with [round] vowels. The neutral vowels /a,e/ which are neither

[high] nor [round] and the mixed vowel /u/ which is both [high] and [round] (the shaded cells) do not have a fixed order with respect to one another.

We conclude that the vocalic and consonantal OCP-effects sometimes add up to a categorical regularity, sometimes to a quantitative tendency. Such effects have been reported for various languages, e.g. Arabic (Frisch et al. 1997), English (Berkley 1994, Guy and Boberg 1997), Korean (Liberman 1994, Kang 1996), and Latin (Liberman 1994). However, there remain cases that the OCP does not explain. We now turn to the morphological and lexical conditions involved.

3.4. The morphological effect

We have seen that the choice between mutation and deletion is to a significant extent determined by phonology. However, the morphologically and lexically conditioned cases remain as puzzling as ever. For example, all the following stems have a penult /a/ followed by a coronal consonant, yet they part company: one mutates, one deletes, one varies. Why?

(21)	a.	/tavara/	tavaro-i-ssa	'thing-PL-INE'
	b.	/jumala/	jumal-i-ssa	'God-PL-INE'
	c.	/itara/	itaroi-ssa∼itar-i-ssa	'stingy-PL-INE'

The crucial morphological generalization was discovered by Göran Karlsson a little over twenty years ago (G. Karlsson 1978). Karlsson observed that free variation of the *itaro-i-ssa∼itar-i-ssa* type had been transforming itself into morphologically conditioned alternation: adjectives had drifted towards deletion, nouns towards mutation. Interestingly, he also noted that this effect was "easiest to observe among nominals ending *-la*, *-na* and *-ra*" (G. Karlsson 1978:87), i.e. in nominals whose final syllable has a coronal onset. Karlsson's best evidence comes from stems that are ambiguous between nouns and adjectives: the noun reading triggers mutation, the adjective reading deletion.

(22)	/kihara/	'curl'	n.	kiharo-i-ssa	M
	/kihara/	'curly'	a.	kihar-i-ssa	D
	/korea/	'Korea'	n.	Koreo-i-ssa	M
	/korea/	'beautiful'	a.	kore-i-ssa	D

The behavior of derivational suffixes confirms G. Karlsson's generalization. Recall from (15) that suffixes with a labial consonant show categorical deletion, suffixes with a dorsal consonant categorical mutation, and after coronals a split pattern emerges. As (23) shows, the split coincides with the part-of-speech boundary: while there is some amount of variation, invariant noun-forming suffixes ($_n$) choose mutation, invariant adjective-forming suffixes ($_a$) deletion.

(23)	coronal	/-isa/$_a$	'-ful'	D	rauha-isa	'peaceful'
		/-ea/$_{a2}$	(lexicalized)	D	kukk-ea	'flowery'
		/-ja/$_n$	'actor'	M∼D	kanta-ja	'carrier'
		/-ea/$_{a1}$	(lexicalized)	M∼D	kukk-ea	'flowery'
		/-la/$_n$	'place'	M	kahvi-la	'café'
		/-nta/$_n$	'nominalizer'	M	ota-nta	'sampling'
		/-na/$_n$	'nominalizer'	M	kirku-na	'screaming'
		/-usta/$_n$	(lexicalized)	M	hiil-usta	'embers'

The diachronic drift observed by G. Karlsson is clearly a case of LEXICAL DIFFUSION (Wang 1969, Labov 1994, Kiparsky 1989, Kiparsky 1995): the drift has been happening gradually, lexical item by lexical item. We even find an occasional word that has travelled against the current. A case in point is the noun *jumala* 'God', crucially a phonologically neutral /a/+coronal stem. In the 19th century, we see it mutate (*jumalo-i-ssa*, Ahlqvist 1877, G. Karlsson 1978:90). In modern standard Finnish only *jumal-i-ssa* is possible.

The upshot is that morphological and lexical effects emerge in environments where the dissimilatory effects are at their weakest. This is also where we found the highest concentration of variable stems in the dictionary. Thus, the adjective *ahkera* 'diligent' has shifted from variation to categorical deletion, whereas the adjective *rivakka* 'brisk' continues to undergo categorical mutation. Similarly, the noun *akana* 'chaff' has shifted from variation to categorical mutation, whereas the noun *pisama* 'freckle' continues to undergo categorical deletion. The reason is phonological: the [high] consonant *k* in *rivakka* and the [round] consonant *m* in *pisama* protect these stems from the morphological forces of analogy.

These observations can be summarized as the following generalization:

(24) THE EMERGENCE OF MORPHOLOGY: Extraphonological (morphological, lexical) conditions emerge in environments where the phonological conditions are at their weakest.

The intuition behind Emergence of Morphology is simple: if phonology fully determines an alternation, or is heavily biased towards one alternant, morphology will not use such an alternation to set up a contrast, say, between nouns and adjectives. In contrast, if phonology does not favor any particular outcome, we have a possible locus for the expression of morphological meanings. In the remaining sections, we will outline a theory of phonology/morphology interaction that derives this generalization.

3.5. Summary

We have now covered the basic facts concerning the behavior of stem-final /a/ before the plural /i/ in Finnish. As is well-known from traditional descriptions, in some cases /a/ mutates to *o*, in other cases it deletes. The problem is to figure out the conditions that determine the choice. We have found two kinds of phonological conditions:

(25) a. CATEGORICAL PHONOLOGICAL CONDITIONS. In nonderived even-numbered stems, deletion applies after rounded vowels (*muna* 'egg') and mutation applies elsewhere (*kana* 'chicken'). This regularity has very few exceptions.

b. PHONOLOGICAL TENDENCIES. In nonderived odd-numbered stems, deletion typically applies after rounded vowels and/or labial consonants (*glaukooma* 'glaucoma'), whereas mutation typically applies after high vowels and/or dorsal consonants (*mansikka* 'strawberry'). This is only a tendency, not a categorical regularity.

In addition, morphological and lexical conditions are also found. In *Nykysuomen sanakirja*, these are described in terms of declensions.

(26) a. MORPHOLOGICAL CONDITIONS. Nouns typically mutate, adjectives typically delete, especially if the phonological conditions are weak or nonexistent (Emergence of Morphology).

b. LEXICAL CONDITIONS. Individual stems may choose their alternation type idiosyncratically, especially if the phonological conditions are weak or nonexistent (Emergence of Morphology).

The entire alternation system is grounded in two simple and general phonological principles: roundness and height dissimilation. In some environments these principles are strong and yield categorical outcomes. In others they are weak and yield morphological and lexical subregularities and statistical tendencies. However, even here the influence of phonology is clearly felt. The challenge is to derive the whole range of surface effects from general grammatical principles. This is the task to which we shall now turn.

4. Analysis

4.1. The constraints

We first need constraints that capture roundness and height dissimilation. OCP[round] and OCP[high] are obviously good candidates. Two important issues arise: (i) The dissimilation effect is strong in even-numbered stems, but weak in odd-numbered stems. How can we account for this syllable-counting effect? (ii) The OCP applies in two different domains: to adjacent syllable nuclei (the vowel effect) and to adjacent segments (the consonant effect). How can this diversity within the OCP be captured?

We approach these problems by splitting the OCP into domain-specific instantiations as follows:

(27)	a.	OCP/V[rd]$_\phi$	No adjacent [round] nuclei within a foot.
		OCP/V[rd]	No adjacent [round] nuclei.
		OCP/S[rd]	No adjacent [round] segments.
	b.	OCP/V[hi]$_\phi$	No adjacent [high] nuclei within a foot.
		OCP/V[hi]	No adjacent [high] nuclei.
		OCP/S[hi]	No adjacent [high] segments.

We propose that vocalic dissimilation within a foot is stronger than vocalic dissimilation across feet, perhaps universally. This is consistent with Mohanan's (1993) proposal regarding assimilation: the smaller the domain, the stronger the effect.[3] We account for the syllable-counting effect by ranking the foot-internal OCP above the general OCP.

[3]A related, but different hypothesis is explored by Frisch, Broe and Pierrehumbert who propose that the strength of place dissimilation in Arabic is a function of the distance of the dissimilating elements (Frisch 1996, Frisch et al. 1997) as well as their location in the word (Frisch 2000). Both effects are then explained in terms of lexical processing (Frisch et al. 1997, see also Boersma 1998, Ch. 18).

(28) a. OCP/V[rd]$_\phi$ ≫ OCP/V[rd] (specific ≫ general)
b. OCP/V[hi]$_\phi$ ≫ OCP/V[hi] (specific ≫ general)

As we shall see shortly, these rankings predict that dissimilation applies more stringently in even-numbered stems than odd-numbered stems, as long as feet are binary and adjacent. The reverse ranking where the general OCP dominates the foot-specific OCP would incorrectly predict that dissimilation is equally strong within and across feet in Finnish, missing the syllable count generalization.

We also propose the following faithfulness constraints:

(29) *DEL Don't delete vowels.
*MUT Don't mutate vowels.

These constraints should be understood as a convenient shorthand. Assuming that *a* = [+low,–round], *o* = [–low,+round] and that ∅ (= deleted segment) has neither feature, we could decompose *MUT into IDENT([low]) and IDENT([round]) and *DEL into MAX([low]) and MAX([round]), following McCarthy and Prince 1995:16. To simplify presentation, we will continue to use *DEL and *MUT in the tableaux.

Finally, the fact that /a+i/ cannot be realized faithfully as either *a.i* (hiatus) or *ai* (diphthong) implies the existence of some high-ranking markedness constraint(s). The hiatus *a.i* can be ruled out by a high-ranking ONSET which requires that syllables have onsets (see e.g. Casali 1996:20). To rule out *ai*, we need to understand what markedness force is targeting /a/ in the first place. Itkonen 1942 suggests that the change *ai* > *oi*∼*i* involves height assimilation to the following *i*. He also points out that the alternation occurs in "non-primary-stressed syllables which due to their relatively weak intensity easily become susceptible to such changes" (Itkonen 1942:117). Here we will simply assume a constraint **ai*. For the purposes of the present analysis, ONSET and **ai* are assumed to dominate the constraints in (27) and (29). They will not be explicitly mentioned in the tableaux.

4.2. The categorical regularities

Exceptionless phonological regularities that hold across all lexical items, no matter whether derived or nonderived, nouns or adjectives, are small in number and limited in scope. One such strict phonological regularity is deletion after /o/ in even-numbered stems.

(30) a. /osa/ os-i-ssa/*oso-i-ssa 'part-PL-INE'
b. /synagooga/ synagoog-i-ssa/*synagoogo-i-ssa 'synagogue-PL-INE'

First, we reformulate the syllable-counting generalization in terms of foot structure. Finnish feet are trochaic, assigned from left to right, with primary stress on the leftmost foot, e.g. (X́.X)(X̀.X) (Sadeniemi 1949, Carlson 1978, Hanson and Kiparsky 1996, Elenbaas 1999, Elenbaas and Kager 1999). The proper statement of the syllable-counting generalization is the following: roundness dissimilation is categorical within feet, but not across feet. To ensure this, we must rank foot-internal roundness dissimilation higher than any constraint that might potentially conflict with it. The ranking in (31) is sufficient.

(31)

/osa+i+ssa/	OCP/V[rd]$_\phi$	OCP/S[hi]	*DEL
1a. *(ó.sois).sa	*!		
1b. ⇒ (ó.sis).sa			*
/synagooga+i+ssa/			
2a. *(sý.na).(gòo.gois).sa	*!		
2b. ⇒ (sý.na).(gòo.gis).sa		*	*

This result generalizes to all even-numbered stems, but crucially, only as long as footing is binary and feet adjacent. In situations where footing is either ternary or skips a syllable, the predictions of syllable counting and foot structure diverge. Fortunately, such examples exist, so we can put the two hypotheses to test. When a light odd syllable is followed by a heavy even, the odd syllable is skipped: (X́.X).L.(H̀.X). It is precisely such examples that establish the correctness of the foot-based formulation. In four-syllable stems like *ravinto-la* 'restaurant' (lit. 'nourishment-PLACE') mere syllable counting wrongly predicts deletion because of the third syllable /o/ (**ra.vin.to.l-i-ssa*), whereas foot structure correctly predicts mutation:

(32) (rá.vin).to.(lò-i-s.sa) 'in the restaurants'

Cases like this show that the true generalization is based on foot structure, not syllable count. They also support an analysis of Finnish in which the light syllable is skipped, preserving trochaic foot form.

We have now accounted for one categorical regularity. There are two more to come. Among odd-numbered stems, there are two environments where mutation is virtually categorical: the environment *k, g* and the environment *i*. First, consider the consonantal environment. If the preceding consonant is [high], mutation is categorical, except if the vowel is [round].

(33)

/mansikka/	mansiko-i-ssa/*mansik-i-ssa	'strawberry-PL-INE'
/mellakka/	mellako-i-ssa/*mellak-i-ssa	'riot-PL-INE'
/kopeekka/	kopeeko-i-ssa/*kopeek-i-ssa	'kopeck-PL-INE'

We must now find a ranking that guarantees these outputs. This is straightforward: since the consonants *k, g* encourage mutation and the vowels either encourage mutation or are neutral, there remains only one constraint that potentially opposes mutation: the faithfulness constraint *MUT. The correct result is guaranteed by ranking *MUT below consonantal height dissimilation.[4]

(34)

/mansikka+i+ssa/	OCP/S[hi]	*MUT
1a. ⇒ (mán.si).(kòis.sa)		*
1b. *(mán.si).(kìs.sa)	*!	
/mellakka+i+ssa/		
2a. ⇒ (mél.la).(kòis.sa)		*
2b. *(mél.la).(kìs.sa)	*!	
/kopeekka+i+ssa/		
3a. ⇒ (kó.pee).(kòis.sa)		*
3b. *(kó.pee).(kìs.sa)	*!	

[4]The facts seem to warrant an even stronger statement: mutation is also categorical in the environment /u/+dorsal, e.g. *puolukka* 'lingonberry'. However, since the vowel /u/ activates roundness dissimilation, deletion remains phonologically possible given the ranking in (34). If we insist on blocking **puoluk-i-ssa* in phonology, the best try would be to add the ranking OCP/S[hi] ≫ OCP/V[rd] into the grammar. Unfortunately, this results in four errors elsewhere in the vocabulary, predicting categorical mutation in *livohka* 'hiding', *mahorkka* 'Russian tobacco' and *revohka* 'scandal' which are variable and also in *subrovka* (apparently a brand of Polish vodka) which according to *Nykysuomen sanakirja* is a categorical deletion stem. Instead of making the absence of deletion in *puolukka*-stems a phonological fact, we suggest it has a morphological origin: of the 91 stems of this type (/u/+dorsal), 88 are nouns and only 3 adjectives. Since nouns tend to choose mutation over deletion, it is not surprising that deletion is not found.

Next, consider the vocalic environment: if the vowel is [high], then mutation is categorical except if the consonant is [round].

(35)

/apina/	apino-i-ssa/*apin-i-ssa	'monkey-PL-INE'
/mansikka/	mansiko-i-ssa/*mansik-i-ssa	'strawberry-PL-INE'

Again, the relevant ranking is easy to find. Since *i* encourages mutation and the consonants either encourage mutation or are neutral, there remains only one constraint that potentially opposes mutation, which is again the faithfulness constraint *MUT. Again, the correct result is guaranteed once we make sure that *MUT is dominated by vocalic height dissimilation.

(36)

/apina+i+ssa/	OCP/V[hi]	*MUT
1a. ⇒ (á.pi).(nòis.sa)		*
1b. *(á.pi).(nìs.sa)	*!	
/lusikka+i+ssa/		
2a. ⇒ (lú.si).(kòis.sa)		*
2b. *(lú.si).(kìs.sa)	*!	

If the consonant is [round] as in *vaati-va* 'demand-PCP', the constraint OCP/S[rd] is activated and deletion is correctly predicted to remain a possibility: *vaati-v-i-ssa*/**vaati-vo-i-ssa*.

The rankings are summarized in (37):

(37)

a.	OCP/V[rd]$_\phi$ ≫ OCP/V[rd]		(universal)
b.	OCP/V[hi]$_\phi$ ≫ OCP/V[hi]		(universal)
c.	OCP/V[rd]$_\phi$ ≫ *DEL	*(ó.s-i-s)sa*	(Finnish)
d.	OCP/V[rd]$_\phi$ ≫ OCP/S[hi]	*(sý.na)(gòo.g-i-s)sa*	(Finnish)
e.	OCP/V[hi] ≫ *MUT	*(á.pi)(nò-i-s.sa)*	(Finnish)
f.	OCP/S[hi] ≫ *MUT	*(mél.la)(kò-i-s.sa)*	(Finnish)

The rankings in (37) guarantee the iron-clad phonological regularities that hold categorically across all lexical items. However, such regularities are few and all very limited in scope. The question now arises how the analysis can be extended to handle subregularities (declensions, lexical exceptions).

It may come as a surprise that the analysis is already in place. All we need to do is look at the simple grammar in (37) from the right point of view and we will find that it already predicts a limited range of subregularities that match the actual declensions of Finnish reasonably well. These predictions only need to be pointed out.

4.3. Deriving declensions

The rankings in (37) capture the categorical regularities in the Finnish data. They also significantly reduce the number of possible grammars. In the absence of any rankings, our eight constraints yield 8! = 40,320 possible total orders. Imposing the six binary rankings in (37) reduces the number to 1,136. All these grammars will clearly guarantee the categorical regularities because the rankings in (37) hold true of all of them. However, the grammars also differ in various ways because most of the rankings are not fixed.

The schematic ranking in (37) is a PARTIAL ORDER. In a total order every constraint is ranked with respect to every other constraint; in a partial order the ranking may remain incomplete. To qualify as a partial order, a ranking relation has to satisfy three requirements (see Partee et al. 1993:39-53):

(38) Let C be a set of constraints and R a binary ranking relation on C. R is a PARTIAL ORDER iff it is irreflexive, asymmetric and transitive.

a. IRREFLEXIVITY. R is irreflexive if and only if for every x in C, R contains no ordered pair $\langle x, x\rangle$ with identical first and second members. (No constraint can be ranked above or below itself.)

b. ASYMMETRY. R is asymmetric if and only if for any ordered pair $\langle x, y\rangle$ in R the pair $\langle y, x\rangle$ is not in R. (If x is ranked above y, it cannot be ranked below y.)

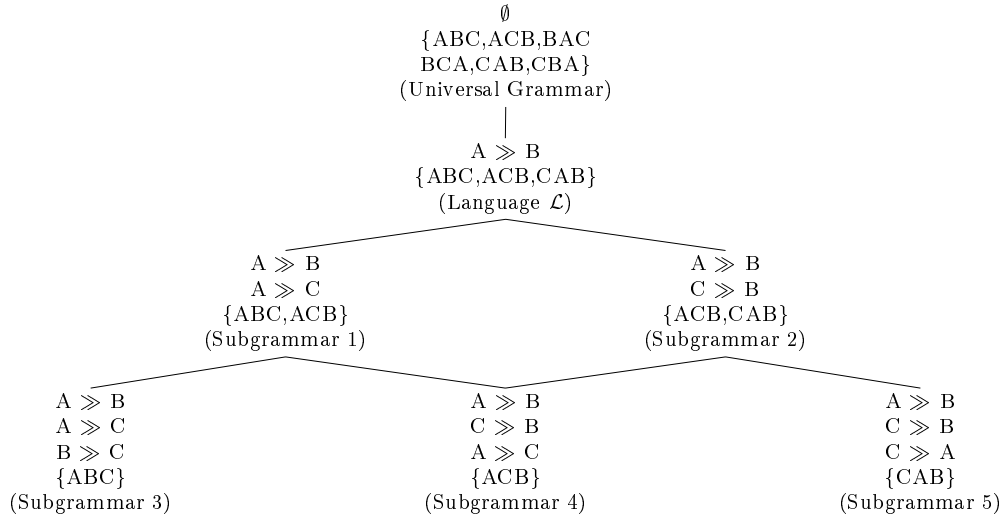
c. TRANSITIVITY. R is transitive if and only if for all ordered pairs $\langle x, y\rangle$ and $\langle y, z\rangle$ in R, the pair $\langle x, z\rangle$ is also in R. (If x is ranked above y and y is ranked above z, then x is ranked above z.)

Universal Grammar is a partial order of a very general sort. In our analysis, it consists of eight constraints and two binary rankings, those given in (37a–b). This schematic ranking yields a large number of possible total orders (10,080). The grammar of Finnish is a more specific partial order: in addition to the two universal rankings, it contains four Finnish-specific binary rankings, those given in (37c–f). This yields a smaller set of possible total orders (1,136). In this sense, Finnish is literally a proper subset of Universal Grammar. By adding more rankings we can define various subsets of Finnish. The resulting partial orders will be increasingly specific and contain fewer and fewer total orders. The most specific partial order is one where every constraint is ranked with respect to every other constraint which equals a

single total order. As a reviewer points out, the learning of optimality-theoretic grammars as envisaged by e.g. Tesar and Smolensky 1998 proceeds analogously, by imposing increasing specificity on the initially unranked or partially ranked grammar.

The resulting structure where more general grammars subsume more specific grammars can be visualized as a LATTICE DIAGRAM. Figure (39) illustrates this by means of three imaginary constraints, A, B and C.

(39) A grammar lattice



In this hypothetical example, the most general grammar (Universal Grammar) contains no rankings ($\emptyset$) which translates into six total orders (ABC, ACB, BAC, BCA, CAB, CBA). Language $\mathcal{L}$ is more specific in containing one ranking (A $\gg$ B) which translates into three total orders (ABC, ACB, CAB). The diagram shows that language $\mathcal{L}$ subsumes five partial orders, three of which are total orders (subgrammars 3, 4 and 5).

Building on earlier proposals in Anttila 1997 and Inkelas 1998, we are now ready to state our main proposal:

(40) The proposal:

a. Grammars are partial orderings of optimality-theoretic constraints.

b. SUBREGULARITY INTERPRETATION: The partial orders within a language are the possible subregularities (declensions, lexical exceptions, etc.) in that language.

Our hypothesis thus claims that the 1,136 total orders define the overall space of the morphological and lexical subregularities of Finnish. Note that this does not necessarily mean that Finnish has 1,136 declensions; different total orders may well generate the same output. To find out how close to the truth our hypothesis is, we compute the outputs for all the 1,136 total orders, for all types of inputs, and match the predictions with the actually attested declensions. If our hypothesis is correct, we would expect to find a good match between the predicted subregularities and the actually observed declensions. A perfect match would mean that all and only the attested declensions are predicted. More realistically, one might expect that all the attested declensions are predicted, although it would not be very surprising to find that some phonologically possible declensions are not realized in the particular dialect we are examining: the dialect described in *Nykysuomen sanakirja*. In what follows, we will systematically spell out the predictions of the schematic grammar in (37) and see how well they fit the facts.

Let us start by considering stems where the alternating vowel is adjacent to a dorsal consonant, e.g. *mansikka* 'strawberry'. The 1,136 total orders yield only three distinct declensions. All three are found.

(41) Predicted and observed declensions in the V+C[high] environment

	/i/	/a,e/	/u/	/o/	EXAMPLES
1.	M	M	M	M (odd only)	*-kka*$_n$, *-kka*$_a$ *-ska*
2.	M	M	M	D	*-ska*
3.	M	M	D	D	*akka, synagooga*

The first declension, mutation across the board, is predicted to be possible only in odd-numbered stems. The actual examples include the lexicalized suffixes *-kka*$_n$ (*silmu-kka* 'loop') and *-kka*$_a$ (*kuula-kka* 'crisp'). These suffixes are only found in trisyllabic stems.[5] The analysis predicts that if they ever occurred in even-numbered stems, they would have to undergo deletion at

[5]This is an instance of a much more general phenomenon, SYLLABLE-COUNTING MORPHOLOGY: different suffixes subcategorize for stems that have an odd vs. even number of syllables. Syllable-counting morphology is a common feature of Finnish (see e.g. Anttila 1997a, Anttila and Cho 1998) and related languages like Estonian (Hint 1980, Kager 1996), Saami (Hargus 1993, Dolbey 1996) and Nganasan (Helimski 1998). The phenomenon is essentially metrical: the alternation of stressed and unstressed syllables is reflected in morphology.

least after /o/ for purely phonological reasons. This is exactly what happens with *-ska*, as we shall now see.

The second declension, mutation after all vowels except /o/, is also attested. The relevant example is the productive suffix *-ska* 'female'. This suffix appears on both even and odd stems: in odd stems it follows declension 1, in even stems declension 2. In other words, *-ska* chooses deletion in exactly one environment: after /o/ in even-numbered stems. The relevant odd/even contrast is illustrated by the minimal pair (42):

(42) a. /rehtor-ska-i-ssa/ (réh.tors)(kò-i-ssa) 'rector's wife'
b. /professor-ska-i-ssa/ (pró.fes)(sòrs.k-i-s)sa 'professor's wife'

The third declension is densely populated. It contains virtually all non-derived even-numbered stems such as *akka* '(old) woman' and *synagooga* 'synagogue'. These stems obey the basic rule "deletion after rounded vowels, mutation elsewhere".

We now turn to stems where the alternating vowel is adjacent to a coronal consonant, e.g. *omena* 'apple'. In addition to the three familiar declensions, two new declensions are predicted to be possible in this environment. At least three and arguably all five are found.

(43) Predicted and observed declensions in the V+C[coronal] environment

	/i/	/a,e/	/u/	/o/	Examples
1.	M	M	M	M (odd only)	*-la, -nta*
2.	M	M	M	D	*-nta*
3.	M	M	D	D	*kana, anafora*
4.	M	D	M	D	*-na*
5.	M	D	D	D	*-ja*$_2$, *-isa*

Declension 1, mutation across the board, is again predicted to be possible only in odd-numbered stems. An actual example is the suffix *-la* 'place', as in *kahvi-la* 'café'. This suffix only occurs in trisyllabic stems and those quadrisyllabic stems that for the purposes of footing count as odd-numbered, e.g. *Kaleva-la* 'Kalevala': *(Ká.le).va.(lòis.sa)*. Again, we predict that if *-la* ever occurred in even positions, it would have to undergo deletion at least after /o/ for purely phonological reasons, but as it is, it never appears in such environments. Declension 3 is again densely populated: it contains stems like *kana* 'hen' and *anafora* 'anaphora' that obey the basic rule "deletion

after rounded vowels, mutation elsewhere". The new declension 5 is easily identified with the suffix *-ja*$_2$ 'actor': mutation after /i/, deletion elsewhere.

Let us now consider declensions 2 and 4. We first note that *-nta* 'nominalizer' fits declension 2 and *-na* 'nominalizer' fits declension 4. However, these suffixes warrant a special mention. In order to conclusively show that a given suffix instantiates these patterns, we need to catch it after all four types of vowels and see whether it undergoes mutation or deletion. However, this is not always possible because some suffixes have defective distributions, among them *-nta* and *-na*. These suffixes are systematically absent after certain vowels. What is more, the distributional gaps do not seem totally random.

The nominalizing morpheme *-nta* occurs in both odd and even positions. However, in even-numbered stems we find a distributional gap: *-nta* occurs after /i,a,e,u/ where it mutates, but in the /o/-environment a different allomorph *-nti* is used. Thus, we get *(pá.hek).(sù-n.ta)* 'disapproval', but *(vá.ras).(tòi-n.ti)* 'storing'. The descriptive nominalizer *-na* only occurs after high vowels /i,u/, e.g. *nari-na* 'squeaking', *kirku-na* 'screaming', mutating in both environments. After /a,e,o/ this suffix is systematically absent.[6] Finally, the adjective-forming suffix *-isa* only occurs after /a,e,u,o/, e.g. *rauha-isa* 'peaceful', *kaste-isa* 'dewy', *mehu-isa* 'juicy', *koto-isa* 'homely', undergoing deletion in all these enviroments. It systematically avoids the /i/-environment.

All these curious gaps can be explained if we assume that *-nta*, *-na* and *-isa* indeed belong to declensions 2, 4 and 5, respectively, but that they also exhibit a strong paradigm uniformity effect. Under this scenario, *-nta* and *-na* preserve their flawless "mutation only" paradigm by simply avoiding environments where they would be phonologically forced to undergo deletion. Similarly, *-isa* preserves its "deletion only" paradigm by refusing to occur after /i/ where phonology would inevitably force mutation. Unfortunately, this explanation does not go all the way: paradigm uniformity is violated by both *-ska* 'female' and *-ja* 'actor' which have paradigms with both mutation and deletion. Thus, we conclude that the suffixes *-nta*, *-na* and *-isa* belong to declensions 2, 4 and 5, respectively; this is clearly warranted by the facts. The fact that these suffixes avoid certain vocalic environments may be a paradigm uniformity effect—and note—one that crucially refers to the phonological

[6] *Nykysuomen sanakirja* has one single counterexample: *ulvo-na* 'howling' which is listed as mutating.

analysis developed here. However, since paradigm uniformity fails in at least two cases, we must leave this as a speculative suggestion.

Finally, we consider stems where the alternating vowel is adjacent to a labial consonant, e.g. *pisama* 'freckle'. In this environment, an additional sixth declension is predicted: deletion across the board.

(44) Predicted and observed declensions in the V+[round] environment:

	/i/	/a,e/	/u/	/o/	EXAMPLES
1.	M	M	M	M (odd only)	*leukooma*
2.	M	M	M	D	
3.	M	M	D	D	*kaava, aksiooma*
4.	M	D	M	D	
5.	M	D	D	D	
6.	D	D	D	D	*-va, -ma, -mpa, -lma, -rva*

Declension 6 is very popular: all suffixes with a labial consonant follow this pattern. Of the already familiar patterns, we continue to predict declension 3, which is crowded as usual, containing stems like *kaava* 'formula' and *aksiooma* 'axiom'. Evidence for the existence of declension 1 is limited to one single stem: *leukooma* 'leucoma' which shows variable mutation after /o/. Declensions 2, 4 and 5 continue to be predicted, but we have not found any unambiguous examples. From the point of view of the model, these are accidental gaps.

The remaining question is how these various declensions can be characterized in terms of grammar. In the proposed system, Universal Grammar, the general phonology of Finnish, and the specific declensions of Finnish are partial orders of increasing specificity. The general phonology of Finnish defines the space of phonologically possible declensions by the rankings in (37). Within this space, individual lexical items may exercise their morphological and lexical freedom, but only by imposing further rankings, thus limiting themselves to various subsets of Finnish phonology. For example, the declension of the suffix *-kka* (mutation in all environments) can be captured by adding a single binary ranking *DEL $\gg$ OCP/V[rd] to the general phonology of Finnish. The entire declensional system is described in the Appendix.

An interesting consequence of the partial ordering approach to declensions is that the superficially most complicated declensions may turn out to be the simplest of all in terms of grammar. The suffix *-ja*$_1$ 'actor' described in *Nykysuomen sanakirja* is a case in point:

(45) The declension of -ja_1 'actor'

	/i/	/a,e/	/u/	/o/
Odd:	M	∼	∼	∼
Even:	M	∼	∼	D

This suffix shows variation everywhere except in two environments: (i) after /i/ where we find categorical mutation; (ii) after /o/ in even-numbered stems where we find categorical deletion. Strikingly, this is exactly the pattern predicted by the general phonology of Finnish for a suffix of this phonological shape:

(46) Predicted declensions in the V+C[coronal] environment

	/i/	/a,e/	/u/	/o/
1.	M	M	M	M (odd only)
2.	M	M	M	D
3.	M	M	D	D
4.	M	D	M	D
5.	M	D	D	D

In the /i/-column, we only find mutation. In the /o/-column, only deletion is possible for even-numbered stems. In all other columns, both mutation and deletion are found. Thus, all we need to say about -ja_1 is that it is Finnish and thus subject to the regular phonology of Finnish. Its phonological behavior follows automatically. Despite its apparently complex variable behavior, nothing special about this suffix needs to be said.

In treating declensions as partial orderings we are adopting a restrictive version of the cophonology model advocated by e.g. Orgun 1996 and Inkelas 1998. A common objection to cophonologies is the possibility of "cophonological explosion": if one cophonology is allowed for one exceptional pattern, so goes the argument, then any number of cophonologies of any kind must be allowed, hence anything can be described and the theory becomes vacuous. This objection is often accompanied by worries about the excessive number of grammars. Partial ordering is an answer to this criticism. The possible subregularities are not a random collection, but a natural class: by the Subregularity Interpretation they are exactly those partial orders subsumed by the categorical phonology of the language. The Finnish example also shows that—despite the large number of total orders—the number of predicted declensions can be surprisingly small.

4.4. The emergence of morphology

Morphological and lexical conditions do not occur randomly. Instead, they follow a particular phonological rationale. This is the observation we dubbed Emergence of Morphology.

(47) The Emergence of Morphology: Extraphonological (morphological, lexical) conditions emerge in environments where the phonological conditions are at their weakest.

We will now show that Emergence of Morphology follows from our theory with no special stipulation. Let us start from the part-of-speech effect. The facts are straightforward: nouns tend to mutate and adjectives delete in environments where the dissimilatory tendencies are at their weakest, that is, where the preceding vowel and the preceding consonant are neither [round] nor [high]. To capture the difference between parts of speech, we posit two minimally different rankings: *DEL ≫ *MUT for nouns, *MUT ≫ *DEL for adjectives.

(48)

	/tavara+i+ssa/$_{noun}$	*DEL	*MUT
1a.	⇒ (tá.va).(ròis.sa)		*
1b.	*(tá.va).(rìs.sa)	*!	
	/avara+i+ssa/$_{adjective}$	*MUT	*DEL
2a.	*(á.va).(ròis.sa)	*!	
2b.	⇒ (á.va).(rìs.sa)		*

Crucially, this does not entail that all nouns will mutate and all adjectives delete. The stems *tavara* and *avara* are special precisely because they are phonologically neutral: since the dissimilation constraints are inactive the decision falls upon the low-ranking faithfulness constraints *Del and *Mut. In stems where the dissimilation constraints are active, something else will happen. We illustrate this with the adjective *kuulakka* 'clear' which is categorically mutating:

(49)

	/kuulakka+i+ssa/$_{adjective}$	OCP/S[hi]	*MUT	*DEL
1a.	⇒ (kúu.la).(kòis.sa)		*	
1b.	*(kúu.la).(kìs.sa)	*!		*

Here mutation is forced by the ranking OCP/S[hi] ≫ *MUT which is part of the general phonology of Finnish. The same will happen in all /i,a,e/+dorsal stems, nouns as well as adjectives. The adjective-specific ranking *MUT ≫ *DEL may well be present, but it is swamped by higher-ranking phonological constraints. Thus, we may assume that adjectives generally subscribe to the ranking *MUT ≫ *DEL, but this special ranking will only emerge if it is not masked by phonology. In other words, we have derived the Emergence of Morphology.

This example reveals a parallel between Emergence of Morphology and Emergence of the Unmarked (McCarthy and Prince 1994). Unmarked structure emerges if a marked structure is not enforced by some higher-ranking constraint (Emergence of the Unmarked). Morphological conditioning may emerge if the outcome is not determined by some higher-ranking phonological constraint (Emergence of Morphology). However, while Emergence of the Unmarked always takes place when higher-ranking constraints do not intervene, Emergence of Morphology is merely available. The other option is variation, attested in lexical items like /itara/ 'stingy, a.' *itaroissa*∼*itarissa* which for some reason do not conform to the categorical deletion pattern typical of adjectives.

Finally, consider lexical exceptions. The noun *jumala* 'God' is of type /a/+coronal, i.e. phonologically neutral. We would thus expect it to fall prey to the morphological mutation tendency. Instead, *jumala* chooses deletion. This is a bona fide lexical exception that to the best of our knowledge has no general explanation. It can be accommodated by associating the stem *jumala* with the "adjective ranking" *MUT ≫ *DEL in the lexicon. However, this is not just a descriptive move: only phonologically neutral stems such as *jumala* can be made exceptional. If we (incorrectly) try to make the noun *silakka* 'Baltic herring' exceptionally deleting, the added ranking will accomplish nothing because phonology will force mutation regardless.

(50)

	/jumala+i+ssa/$_{noun}$	OCP/S[hi]	*MUT	*DEL
1a.	*(jú.ma).(lòis.sa)		*!	
1b. ⇒	(jú.ma).(lìs.sa)			*
	/silakka+i+ssa/$_{noun}$	OCP/S[hi]	*MUT	*DEL
2a. ⇒	(sí.la).(kòis.sa)		*	
2b.	*(sí.la).(kìs.sa)	*!		*

The analysis thus correctly predicts that the part-of-speech effect and lexical exceptions emerge precisely in phonologically neutral environments. This rules out putative lexical exceptions like **silak-i-ssa* as phonologically impossible. More generally, the prediction is that all morphological and lexical effects are subject to phonological restrictions, universal as well as language-specific. Morphological and lexical effects can step in only in environments where phonology does not fully determine the outcome.

4.5. Residual issues

We conclude by mentioning two issues that have not been dealt with. The first is the theoretical interpretation of quantitative regularities. The second is what determines the choice between alternation and variation, i.e. cases where, for a given speaker, a lexical item shows either mutation or deletion, but not both (alternation), and cases where both mutation and deletion are possible (variation).

In earlier work, partially ordered grammars have been used to model token frequencies in cases of variation (Kiparsky 1993, Anttila 1997, Nagy and Reynolds 1997, Anttila and Cho 1998, Ringen and Heinämäki 1999; for an alternative model, see Boersma and Hayes 1999). One possible QUANTITATIVE INTERPRETATION of partial ordering would be to sum up the number of total orders that generate each output and posit this as proportional to the relative frequency of this output. Such an approach could in principle be used to model the quantitative OCP-effects observed in this paper. The main obstacle is the small size of the corpus. Even the largest dictionaries have too few words to instantiate the various phonological possibilities, especially if we want to consider each subregularity separately. Alternative methods (elicitation of grammaticality judgments, token frequencies based on large corpora) would be helpful here. This is left for future work.

If alternation and variation are two different manifestations of phonological subregularities, as we have argued, a further question arises: why do we sometimes get alternation, but no corresponding variation, and conversely, why do we sometimes get variation, but no corresponding alternation? Unlike alternation, variation is often a passing stage signalling change in progress. For example, the suffix *-ja*$_1$ 'actor' described as variable in *Nykysuomen sanakirja* no longer shows variation in current standard Finnish. Similarly, the variation in trisyllabic stems like *ipana* 'kid, n.' and *ahkera* 'diligent, a.' has by and large turned into alternation conditioned by part of speech.

This may suggest that variation is for some reason less stable than alternation and tends to be eliminated from grammar. However, not all variation is short-lived: the Finnish genitive plural paradigm shows extensive segmentally and prosodically conditioned variation that has endured for centuries without either levelling out or becoming morphologically conditioned (Paunonen 1974, Anttila 1997a). Why these two cases should be different is unclear. The explanation may have a partly grammatical basis (Kiparsky to appear), although factors such as lexical frequency may also play a role (Anttila 2000). Be that as it may, the synchronic phonological model presented here is agnostic on these matters. The claim is simply that alternation and variation share the same synchronic phonological mechanism.

5. A comparison with interface constraints

Let us now consider an alternative optimality-theoretic analysis of the Finnish data. A common approach to morphological and lexical effects is to posit phonological constraints that only apply to certain declensions, parts of speech or lexical items. For Finnish, we would need constraints indexed to apply to specific declensions ($\textsc{Faith}_{Declension-15}$), parts of speech ($\textsc{Faith}_{noun}$) and possibly individual lexical items ($\textsc{Faith}_{jumala}$, $\textsc{Faith}_{-kka}$).

First, consider the various suffixal declensions. To describe the fact that *-la* 'place' is mutating and *-ma* 'infinitive' deleting, we could posit the suffix-specific faithfulness constraints $*\textsc{del}_{-la}$ and $*\textsc{del}_{-ma}$, ranked in this order. This ranking could be exploited to derive mutation in *keitto-la* 'kitchen' and deletion in *kerto-ma* 'factorial', as shown in tableau (51).

(51)

/keitto+la+i+ssa/	$*\textsc{del}_{-la}$	OCP/V[rd]	$*\textsc{del}_{-ma}$
1a. ⇒ keitto-lo-i-ssa		*	
1b. *keitto-l-i-ssa	*!		
/kerto+ma+i+ssa/	$*\textsc{del}_{-la}$	OCP/V[rd]	$*\textsc{del}_{-ma}$
2a. *kerto-mo-i-ssa		*!	
2b. ⇒ kertom-i-ssa			*

The problem is that the ranking of the suffix-specific constraints is phonologically motivated: it reflects the familiar consonant hierarchy dorsal > coronal > labial. For this reason, it should follow from phonology, but it does not.

The constraints are suffix-specific and the fact that the consonants happen to be coronal and labial, respectively, is purely coincidental. We could just as well have posited the opposite ranking, $*\text{DEL}_{-ma} \gg *\text{DEL}_{-la}$, which would get us the phonologically less natural and factually wrong results. The upshot is that suffix-specific constraints clearly miss a fundamental phonological generalization.

Next, consider the part-of-speech effect: nouns tend to mutate, adjectives tend to delete. We could account for this effect by positing two part-of-speech-specific phonological constraints $*\text{DEL}_{noun}$ and $*\text{DEL}_{adjective}$, ranked in this order, and by sandwiching a third constraint that resists mutation between the two, as shown in (52).

(52) *kihara* 'curl, n.' vs. *kihara* 'curly, a.'

/kihara+i+ssa/$_{noun}$			$*\text{DEL}_{noun}$	$*\text{MUT}$	$*\text{DEL}_{adjective}$
1a.	⇒	ki.ha.ro-i-s.sa		*	
1b.		ki.ha.ri-s.sa	*!		
/kihara+i+ssa/$_{adjective}$					
2a.		kiharo-i-ssa		*!	
2b.	⇒	kihar-i-ssa			*

A major problem for this approach is that nouns and adjectives are far from homogeneous classes. The part-of-speech generalization discovered by G. Karlsson (1978) is absolutely genuine, but the language is still implementing it. The analogical change has not yet reached all words, and perhaps never will. Consider the phonologically neutral nouns (/a,e/+coronal). In the dictionary, we find 127 that undergo mutation categorically (e.g. *kamera* 'camera', *kakara* 'brat', *legenda* 'legend', *ooppera* 'opera'), 68 that vary (e.g. *algebra* 'algebra', *ipana* 'kid', *omena* 'apple', *vaahtera* 'maple'), and one that undergoes deletion categorically (*jumala* 'God'). Since the compilation of the dictionary many variable nouns have shifted to the mutation class, but not all, and there are individual differences among speakers. In my idiolect, *algebra*, *ipana* and *vaahtera* are already categorically mutating, but *omena* remains variable. This is presumably something that has to be memorized by the language learner.

In order to fix the leaking part-of-speech faithfulness constraints, one might resort to lexeme-specific constraints. For example, the stem *jumala* 'God' is clearly exceptional: it is phonologically neutral (/a/+coronal), and

hence subject to the analogical pressure to mutate, yet it persistently chooses invariant deletion. The obvious solution would be to make up a special constraint for this lexeme, say $*\text{MUT}_{jumala}$ and rank it above $*\text{DEL}_{noun}$ as illustrated in (53).

(53) *jumala* 'God' vs. *kakara* 'brat'

	/jumala+i+ssa/$_{noun}$	$*\text{MUT}_{jumala}$	$*\text{DEL}_{noun}$	$*\text{MUT}$
1a.	*ju.ma.lo-i-s.sa	*!		*
1b. ⇒	ju.ma.l-i-s.sa		*	
	/kakara+i+ssa/$_{noun}$			
2a. ⇒	ka.ka.ro-i-s.sa			*
2b.	*ka.ka.r-i-s.sa		*!	

However, recall that the exceptionality of *jumala* is far from a random fact: *jumala* 'God' can be exceptional precisely because it is a phonologically neutral /a/+coronal stem. In contrast, *silakka* 'Baltic herring' cannot be exceptional because it is an /a/+dorsal stem. In the partial ordering analysis, this follows from phonology. However, once lexeme-specific constraints are allowed, nothing stops us from positing constraints like $*\text{MUT}_{silakka}$, or any lexeme-specific constraint whatsoever, which predicts a vast number of phonologically bizarre and consequently unattested systems. The problem with lexeme-specific constraints is that they make lexical exceptions phonologically arbitrary, which they are not.

The problem we are facing is the synchronic aspect of lexical diffusion (Wang 1969), a species of phonological change that is phonetically abrupt, but lexically gradual, and it is here that interface constraints founder. The analogical change pulling nouns and adjectives apart does not take place instantaneously, but lexical item by lexical item. However, lexical diffusion is not phonologically arbitrary, but proceeds along fixed phonological dimensions (Labov 1994:421-471, Kiparsky 1995). The partial ordering model provides the necessary descriptive freedom, i.e. lexeme-specific rankings, for capturing lexical diffusion effects, while maintaining the fundamental phonological generalizations intact: lexeme-specific phonologies are literally subsets of the general phonology of the language. In contrast, interface constraints are overly powerful. They fail to maintain phonological generalizations and predict large numbers of unattested phonological systems.

Since interface constraints are widely used in the literature, it is worth considering whether there is a way of salvaging the model by imposing principled limits on the ranking of these specialized constraints. A possibility suggested by a reviewer would be to require that lexically specific constraints be subject to all the ranking relations that apply to their general counterparts. This means that if a constraint $\mathcal{C}$ dominates a general constraint $\mathcal{F}$, then it must also dominate its lexically specific counterpart $\mathcal{F}_{special}$. However, recall the analysis of the exceptional lexical item *jumala* 'God' in (53). The required ranking was as in (54):

(54) The ranking for exceptions:

$$\mathcal{F}_{special} \gg \mathcal{C} \gg \mathcal{F}$$

The general case requires the ranking $\mathcal{C} \gg \mathcal{F}$, the special case requires the opposite ranking $\mathcal{F}_{special} \gg \mathcal{C}$. This flatly contradicts the proposed restriction. Worse yet, this is the typical case. Not only may such rankings occur; they must occur if lexically specific constraints are to do any work at all. We conclude that at least this particular attempt to mimic the Subregularity Interpretation clearly fails.

Finally, a general reason for preferring the partial ordering model to the interface constraint model is that the former extends to variation, but the latter does not. Adopting both interface constraints and partial ordering is a possibility, but would further weaken the case for interface constraints because a model with partial ordering only is clearly preferable to a model with both partial ordering and interface constraints, unless it can be shown that a particular interface constraint captures some linguistically significant generalization that partial ordering does not. In the absence of such evidence, partial ordering seems the better of the two theoretical options.

6. Conclusion

Based on evidence from Finnish, we have defended the view that grammars consist of mutually incompatible subregularities, which however are not an arbitrary collection, but a natural class. This position is quite traditional. It is in full agreement with the view expressed by sociolinguists and historical linguists that language is a system possessing "orderly heterogeneity"

(Weinreich et al. 1968). It also agrees with Lexical Phonology and Morphology (Kiparsky 1982, Mohanan 1986, and especially Kiparsky to appear) in assuming that distinct morphological levels (strata) can be associated with distinct, but related phonologies. Finally, it is consistent with the fundamental insights of the proponents of cophonologies (Itô and Mester 1995, Orgun 1996, Inkelas 1998, Kiparsky to appear).

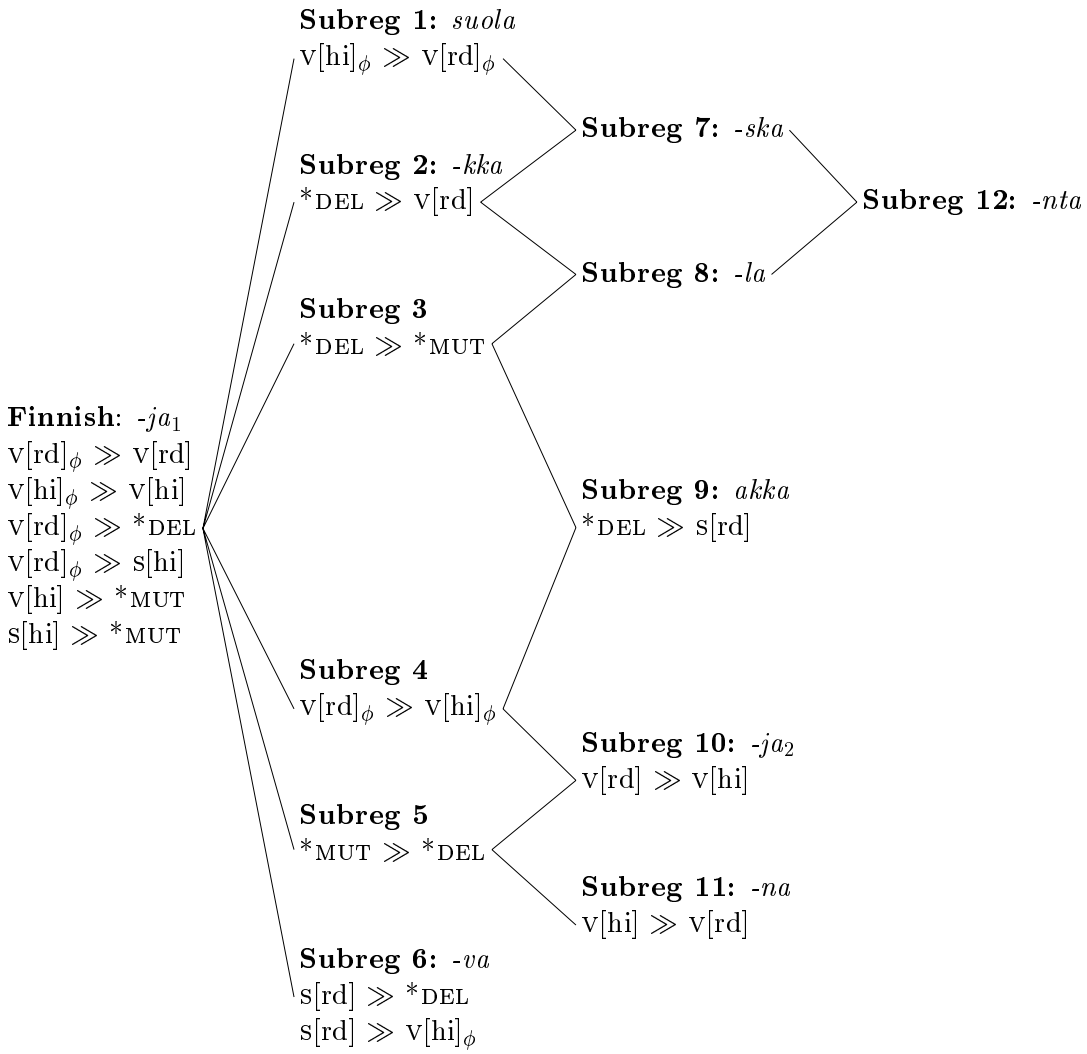
What is new about the partial ordering model is that it puts forward a specific technical proposal concerning the nature of this "orderly heterogeneity" and formalizes it in terms of Optimality Theory. In addition to the Quantitative Interpretation familiar from earlier work, we have proposed another empirical interpretation of the model: the Subregularity Interpretation. The main virtue of the partial ordering model, so interpreted, is that it explicitly connects three seemingly different phenomena: categorical regularities (rules), subregularities (declensions, lexical exceptions), and variation, within one and the same grammar.

Appendix: Finnish declensions

The partial lattice diagram in (55) displays the relationships among the various subregularities of Finnish /a/-final nominals. (A complete diagram, with 1,136 leaves, would not fit on the page.) The diagram shows one workable solution; there are probably others.

The lattice is displayed sideways for typographical reasons, root node on the left. The nodes are labelled by arbitrary reference numbers (e.g. **Subreg 2**) and a sample lexical item is given, if available. Each node inherits the rankings of all the nodes on its left. In particular, all nodes inherit all the rankings of the general phonology of Finnish, located at the root node. Variation decreases as we move from left to right, because additional rankings eliminate outputs. Thus, analogical levelling that leads to loss of variation, e.g. the change from variable ja_1 to the invariant -ja_2, can be visualized as a rightward shift within the lattice.

(55) A grammar lattice for Finnish /a/-final nominals



(56) Examples and surface patterns

Finnish (the general phonology) *-ja*$_1$ 'actor', *-ea*$_1$ (lexicalized). This declension also contains variable stems, including the disyllabic verbs of type *taitta-* 'break'.

	/i/	/a,e/	/u/	/o/
Odd:	M	∼	∼	∼
Even:	M	∼	∼	D

Subreg 1 Exceptionally mutating nouns of type *suola* 'salt'.

	/i/	/a,e/	/u/	/o/
Even:	–	–	M	–

Subreg 2 *-kka*$_n$, *-kka*$_a$ (lexicalized).

	/i/	/a,e/	/u/	/o/
Odd:	M	M	M	M
Even:	–	–	–	–

Subreg 6 The adjectival suffixes *-va* 'PRES.PCP', *-ma* 'INF', *-lma* (lexicalized), *-rva* (lexicalized).

	/i/	/a,e/	/u/	/o/
Odd:	D	D	D	D
Even:	D	D	D	D

Subreg 7 *-ska* 'female', *-usta* (lexicalized).

	/i/	/a,e/	/u/	/o/
Odd:	M	M	M	M
Even:	M	M	M	D

Subreg 8 *-la* 'place'.

	/i/	/a,e/	/u/	/o/
Odd:	M	M	M	M
Even:	–	–	–	–

Subreg 9 Regular even-numbered nominals, e.g. *akka* '(old) woman', *kana* 'hen', *kaava* 'formula', *synagooga* 'synagogue', *anafora* 'anaphora', *aksiooma* 'axiom'.

	/i/	/a,e/	/u/	/o/
Even:	M	M	D	D

Subreg 10 *-ja*$_2$ 'actor', *-isa* '-ful'.

	/i/	/a,e/	/u/	/o/
Odd:	M	D	D	D
Even:	M	D	D	D

Subreg 11 *-na* 'nominalizer'.

	/i/	/a,e/	/u/	/o/
Odd:	M	D	M	D
Even:	–	–	–	–

Subreg 12 *-nta* 'nominalizer'.

	/i/	/a,e/	/u/	/o/
Odd:	M	M	M	M
Even:	M	M	M	D

References

Ahlqvist, August. 1877. *Suomen Kielen Rakennus [The Structure of Finnish].* Helsinki.

Alderete, John. 1999. *Morphologically Governed Accent in Optimality Theory.* Doctoral dissertation, University of Massachussetts, Amherst. `http://www.ruccs.rutgers.edu/roa.html, ROA-309-0399`.

Anttila, Arto. 1997a. Deriving variation from grammar. In Frans Hinskens, Roeland van Hout, and Leo Wetzels (eds.), *Variation, Change and Phonological Theory*, 35–68. Amsterdam/Philadelphia, John Benjamins Publishing Company. Also: `http://www.ruccs.rutgers.edu/roa.html, ROA-63`.

Anttila, Arto. 1997b. *Variation in Finnish Phonology and Morphology.* Doctoral dissertation, Stanford University, Stanford, California.

Anttila, Arto. 2000. Derived environment effects in Colloquial Helsinki Finnish. `http://www.ruccs.rutgers.edu/roa.html, ROA-406-08100`.

Anttila, Arto, and Young-mee Cho. 1998. Variation and change in Optimality Theory. *Lingua* 104, 31–56. Special issue on Optimality Theory.

Beckman, Jill N. 1998. *Positional Faithfulness.* Doctoral dissertation, University of Massachusetts, Amherst. `http://www.ruccs.rutgers.edu/roa.html, ROA-234-1297`.

Benua, Laura. 1995. Identity effects in morphological truncation. In Jill N. Beckman, Laura Walsh Dickey, and Suzanne Urbanczyk (eds.), *Papers in Optimality Theory*, 77–136. University of Massachusetts, Amherst, GLSA.

Benua, Laura. 1998. *Transderivational Identity: Phonological Relations Between Words.* Doctoral dissertation, University of Massachussetts, Amherst. `http://ruccs.rutgers.edu/roa.html/ROA-259-0498`.

Berkley, Deborah Milam. 1994. Variability in Obligatory Contour Principle Effects. In Beals et al. (ed.), *CLS 30, Volume 2: Parasession on Variation in Linguistic Theory*, 1–12. Chicago, CLS.

Boersma, Paul. 1998. *Functional Phonology.* Doctoral dissertation, University of Amsterdam. Published by Holland Academic Graphics, The Hague. Also: `http://uvafon.hum.uva.nl/paul/`.

Boersma, Paul, and Bruce Hayes. in press. Empirical tests of the gradual learning algorithm. *Linguistic Inquiry* 32(1). Also `http://ruccs.rutgers.edu/roa.html, ROA-348-1099`.

Carlson, Lauri. 1978. Word stress in Finnish. Ms., MIT.

Casali, Roderic F. 1996. *Resolving hiatus.* Doctoral dissertation, University of California, Los Angeles. `http://www.ruccs.rutgers.edu/roa.html, ROA-215-0997`.

Chomsky, Noam, and Morris Halle. 1968. *The Sound Pattern of English.* Cambridge, Mass., MIT Press.

Dolbey, Andrew. 1996. Output optimization and cyclic allomorph selection. In Brian Agbayani and Sze-Wing Tang (eds.), *The Proceedings of the Fifteenth West Coast Conference on Formal Linguistics (WCCFL 15)*, 97–112. Stanford Linguistics Association/CSLI.

Elenbaas, Nine. 1999. *Foot typology and ternary stress systems.* Doctoral dissertation, Utrecht Institute of Linguistics OTS. Published by Holland Academic Graphics, The Hague. Also: `http://www.ruccs.rutgers.edu/roa.html, ROA-397-06100`.

Elenbaas, Nine, and René Kager. 1999. Ternary rhythm and the lapse constraint. *Phonology* 16(3), 273–329.

Frisch, Stefan. 1996. *Similarity and Frequency in Phonology.* Doctoral dissertation, Northwestern University. `http://www.ruccs.rutgers.edu/roa.html, ROA 198-0597`.

Frisch, Stefan. 2000. Temporally organized lexical representations as phonological units. In Michael Broe and Janet B. Pierrehumbert (eds.), *Language acquisition and the lexicon: Papers in laboratory phonology V*, 283–298. Cambridge, Cambridge University Press. `http://www.ruccs.rutgers.edu/roa.html, ROA-269-0798`.

Frisch, Stefan, Michael Broe, and Janet Pierrehumbert. 1997. Similarity and phonotactics in Arabic. `http://www.ruccs.rutgers.edu/roa.html, ROA 223-1097`.

Fukazawa, Haruka, Mafuyu Kitahara, and Mitsuhiko Ota. to appear. Lexical stratification and ranking invariance in constraint-based grammars. In *Proceedings of CLS 34*. The Chicago Linguistic Society.

Guy, Gregory, and Charles Boberg. 1997. Inherent variability and the Obligatory Contour Principle. *Language Variation and Change* 9, 149–164.

Halle, Morris. 1992. Phonological features. In W. Bright (ed.), *International encyclopedia of linguistics, Vol. 3*, 207–12. Oxford, Oxford University Press.

Hammond, Michael. 1995. There is no lexicon! `http://www.ruccs.rutgers.edu/roa.html, ROA-43`.

Hanson, Kristin, and Paul Kiparsky. 1996. A parametric theory of poetic meter. *Language* 72, 287–335.

Hargus, Sharon. 1993. Modeling the phonology-morphology interface. In Sharon Hargus and Ellen Kaisse (eds.), *Phonetics and Phonology, Volume 4: Studies in Lexical Phonology*, 45–74. San Diego, California, Academic Press.

Harris, Zellig. 1951. *Structural Linguistics.* Chicago and London, The University of Chicago Press.

Hayes, Bruce. to appear. Gradient well-formedness in Optimality Theory. In Joost Dekkers, Frank van der Leeuw, and Jeroen van de Weijer (eds.), *Optimality Theory: Phonology, Syntax and Acquisition.* Oxford, Oxford University Press. Also `http://www.linguistics.ucla.edu/people/hayes/gradient.htm`.

Helimski, Eugene. 1998. Nganasan. In Daniel Abondolo (ed.), *The Uralic Languages*, 480–515. Routledge.

Hint, Mati. 1980. Minevikuline ja tulevikuline aines keelesüsteemis. Prosoodiatüübi nihked ja selle tagajärjed. *Keel ja Kirjandus* 23, 215–23,270–8,349–55.

Inkelas, Sharon. 1998. The theoretical status of morphologically conditioned phonology: a case study of dominance effects. In Gert Booij and Jaap van Marle (eds.), *Yearbook of Morphology 1997*, 121–155. Kluwer, Kluwer Academic Publishers.

Inkelas, Sharon. 1999. Exceptional stress-attracting suffixes in Turkish: representations versus the grammar. In René Kager, Harry van der Hulst, and Wim Zonneveld (eds.), *The Prosody-Morphology Interface*, 134–87. Cambridge, Cambridge University Press.

Itkonen, Erkki. 1942. Varhaiskantasuomen pääpainottoman *ai*-diftongin kahtalaisen kehityksen syistä [On the causes of the two distinct developments of the Early Proto-Finnic diphthong *ai*]. *Virittäjä* 117–25.

Itô, Junko, and Armin Mester. 1995a. The core-periphery structure in the lexicon and constraints on re-ranking. In Jill N. Beckman, Laura Walsh Dickey, and Suzanne Urbanczyk (eds.), *Papers in Optimality Theory*, 181–210. University of Massachusetts, Amherst, GLSA.

Itô, Junko, and Armin Mester. 1995b. Japanese phonology. In John A. Goldsmith (ed.), *The Handbook of Phonological Theory*, 817–38. Oxford, Blackwell.

Itô, Junko, and Armin Mester. 1998. The phonological lexicon. In Natsuko Tsujimura (ed.), *A Handbook of Japanese Linguistics*. Oxford, Blackwell.

Kager, René. 1996. On affix allomorphy and syllable counting. In U. Kleinhenz (ed.), *Interfaces in phonology*, Studia grammatica 41, 155–171. Berlin, Akademie Verlag. Also: `http://ruccs.rutgers.edu/roa.html, ROA-88`.

Kang, Hyeon-Seok. 1996. The Deletion of *w* in Seoul Korean and its Implications. In David Dowty, Rebecca Herman, Elizabeth Hume, and Panayiotis A. Pappas (eds.), *Working Papers in Linguistics No. 48*, 56–76. The Ohio State University, Department of Linguistics.

Karlsson, Fred. 1982. *Suomen kielen äänne- ja muotorakenne [The Phonological and Morphological Structure of Finnish]*. Helsinki, Werner Söderström Osakeyhtiö.

Karlsson, Göran. 1978. Kolmi- ja useampitavuisten nominivartaloiden loppu-A:n edustuminen monikon *i*:n edellä [The realization of the final A of trisyllabic and longer nominal stems before the plural *i*]. In *Rakenteita. Juhlakirja Osmo Ikolan 60-vuotispäiväksi, 6.2.1978.*, 86–99. Turun Yliopiston suomalaisen ja yleisen kielitieteen laitos.

Keyser, Samuel Jay, and Paul Kiparsky. 1984. Syllable structure in Finnish phonology. In Mark Aronoff and Richard T. Oehrle (eds.), *Language Sound Structure. Studies in Phonology Presented to Morris Halle by His Teacher and Students*, 7–31. Cambridge, Mass., MIT Press.

Kiparsky, Paul. 1982. Lexical morphology and phonology. In I.-S. Yang (ed.), *Linguistics in the Morning Calm.* Seoul, Hanshin.

Kiparsky, Paul. 1989. Phonological change. In Frederick Newmeyer (ed.), *Linguistics: The Cambridge Survey*, 363–415. Cambridge, Cambridge University Press.

Kiparsky, Paul. 1993. Variable rules. Handout distributed at the Rutgers Optimality Workshop (ROW1).

Kiparsky, Paul. 1995. The phonological basis of sound change. In John A. Goldsmith (ed.), *The Handbook of Phonological Theory*, 640–70. Oxford, Blackwell.

Kiparsky, Paul. to appear. *Paradigm Effects and Opacity.* Stanford, California, CSLI Publications.

Labov, William. 1994. *Principles of Linguistic Change: Internal Factors.* Oxford, UK, and Cambridge, USA, Blackwell.

Leben, William R. 1973. *Suprasegmental Phonology.* Doctoral dissertation, Massachusetts Institute of Technology, Cambridge, Mass.

Liberman, Mark. 1994. Optionality and optimality. Fragment of a draft, Department of Linguistics, University of Pennsylvania.

McCarthy, John, and Alan Prince. 1993. Prosodic Morphology I: Constraint Interaction and Satisfaction. University of Massachusetts, Amherst, and Rutgers University.

McCarthy, John, and Alan Prince. 1994. The emergence of the unmarked. `http://www.ruccs.rutgers.edu/roa.html, ROA-13`.

McCarthy, John, and Alan Prince. 1995. Faithfulness and reduplicative identity. In Jill N. Beckman, Laura Walsh Dickey, and Suzanne Urbanczyk (eds.), *Papers in Optimality Theory*, 249–384. UMass, Amherst, GLSA.

Mohanan, K.P. 1986. *The Theory of Lexical Phonology*. Dordrecht, Reidel.

Mohanan, K.P. 1993. Fields of attraction in phonology. In John Goldsmith (ed.), *The Last Phonological Rule*, 61–116. Chicago and London, The University of Chicago Press.

Myers, James. 1999. Lexical phonology and the lexicon. `http://www.ruccs.rutgers.edu/roa.html, ROA-330`.

Nagy, Naomi, and William Reynolds. 1997. Optimality theory and variable word-final deletion in Faetar. *Language Variation and Change* 9(1), 37–55.

Orgun, Cemil Orhan. 1996. *Sign-Based Morphology and Phonology with special attention to Optimality Theory*. Doctoral dissertation, Department of Linguistics, University of California, Berkeley. `http://www.ruccs.rutgers.edu/roa.html, ROA-171`.

Partee, Barbara H., Alice ter Meulen, and Robert E. Wall. 1993. *Mathematical Methods in Linguistics*. Dordrecht, the Netherlands, Kluwer Academic Publishers. Corrected first edition.

Paunonen, Heikki. 1974. *Monikon genetiivin muodostus suomen kielessä I [Genitive plural formation in Finnish, Vol. I]*. Helsinki, Suomalaisen Kirjallisuuden Seura.

Penttilä, Aarni. 1963. *Suomen kielioppi [Finnish grammar]*. Porvoo, Werner Söderström Osakeyhtiö. 2nd revised edition.

Prince, Alan, and Paul Smolensky. 1993. Optimality Theory: Constraint Interaction in Generative Grammar. Rutgers University, New Brunswick, and University of Colorado, Boulder.

Revithiadou, Anthi. 1999. *Headmost Accent Wins*. Doctoral dissertation, Holland Institute of Generative Linguistics. Published by Holland Academic Graphics, The Hague. Also `http://www.ruccs.rutgers.edu/roa.html, ROA-388-04100`.

Ringen, Catherine O., and Orvokki Heinämäki. 1999. Variation in Finnish vowel harmony. *Natural Language and Linguistic Theory* 17, 303–337.

Russell, Kevin. 1995. Morphemes and candidates in Optimality Theory. `http://www.ruccs.rutgers.edu/roa.html, ROA-44-0195`.

Russell, Kevin. 1999. MOT: Sketch of an OT approach to morphology [DRAFT]. `http://www.ruccs.rutgers.edu/roa.html, ROA-352-1099`.

Sadeniemi, Matti. 1949. *Metriikkamme perusteet [The Fundamentals of Finnish Metrics]*. Suomalaisen Kirjallisuuden Seura.

Sadeniemi, Matti (ed.). 1973. *Nykysuomen sanakirja [Dictionary of Modern Finnish]*. Porvoo, Finland, Werner Söderström Osakeyhtiö.

Sagey, E. 1986. *The representation of features and relations in nonlinear phonology*. Doctoral dissertation, MIT.

Smith, Jennifer L. 1997. Noun faithfulness: On the privileged status of nouns in phonology. `http://www.ruccs.rutgers.edu/roa.html, ROA-242-0198`.

Tesar, Bruce, and Paul Smolensky. 1998. Learnability in Optimality Theory. *Linguistic Inquiry* 29, 229–268.

Thymé, Ann, Farrell Ackerman, and Jeff Elman. 1994. Finnish nominal inflection. Paradigmatic patterns and token analogy. In Susan D. Lima, Roberta L. Corrigan, and Gregory K. Iverson (eds.), *The Reality of Linguistic Rules*, 445–466. Amsterdam/Philadelphia, John Benjamins Publishing Company.

Urbanczyk, Suzanne. 1996. *Patterns of Reduplication in Lushootsheed*. Doctoral dissertation, University of Massachusetts, Amherst.

Wang, William S.-Y. 1969. Competing changes as a cause of residue. *Language* 45, 9–25. Reprinted in Baldi, Philip and Ronald N. Werth, eds., 1978. *Readings in Historical Phonology*. University Park and London: The Pennsylvania State University Press.

Weinreich, Uriel, William Labov, and Marvin I. Herzog. 1968. Empirical foundations for a theory of language change. In W.P. Lehmann and Yakov Malkiel (eds.), *Directions for Historical Linguistics: A Symposium*, 95–195. Austin, University of Texas Press.

Wiik, Kalevi. 1984. Miksei *munoja* vaikka *kanoja?* [Why no *eggs*, although *hens*?]. Turku, Finland, Turun Yliopiston Suomalaisen ja yleisen kielitieteen laitos, Publication no. 20.