Rethinking the *Core-Periphery* Model: Evidence from Japanese and English

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April 29, 2016

1 Introduction

This paper is an attempt to more clearly define the relationship between historical change and synchronic phonological systems, explored through the lexical remnants of past sound changes in Japanese and English. The diachronic/synchronic relationship has often been downplayed, if not ignored entirely, throughout the history of modern phonological study, by researchers on both sides of the field. In accounting for the synchronic behavior of modern English, for example, both SPE and Lexical Phonology effectively recapitulate the history of the language since Middle English with no mention of the diachronic parallels to the processes they propose. This also raises the broader issue of the ongoing tension between linguistic change and synchronic language systems in general, with each camp often overlooking the potential input of the other, when in reality they complement each other surprisingly well. As Bermúdez-Otero (2006) stated, "OT provides new angles on long-standing diachronic questions, whilst historical data and models of change bear directly on the assessment of OT". (498)

The goal of generative phonology is to offer as unified an account as possible for all systemic sound alternations present within a given language, but how should we approach the contradictory results of sound change? The most common reaction has been to beef up the power of our phonological models, whether that be by way of the opaque underlying forms proposed by SPE or the compartmentalization seen in Itô and Mester's *Core-Periphery* and Anttila and Cho's *Cophonology* models within OT. I, on the other hand, will argue that much of this residue belongs in the lexicon instead, and that synchronic phonology should be restricted to accounting for truly productive alternations.

To illustrate this point, I examine the changes in the distribution of various phonemes and their surface representations across multiple lexical strata in Japanese and English. I will present the analysis offered by the *Core-Periphery* (CP) model of Itô & Mester (1995), which utilizes rerankings of the FAITH constraint between different lexical strata, to account for the alternations present in the data[1]. This Japanese data has been approached very differently from the English data in the literature, namely, as a problem of synchronic phonology instead of a problem of historical lexical

[1]The *Cophonology* model of Anttila (1997) is an alternative for dealing with stratal variation within Stratal OT. This approach differs from the *Core-Periphery* model by allowing effectively free reranking of all constraints in an arbitrarily large number of strata, not just of the FAITH constraint. As a result, in addition to its generally unconstrained nature, the *Cophonology* model also fails to capture the hierarchical behavior of lexical strata, which is beautifully displayed by the CP model's FAITH rerankings, as seen in Figure (2) in §2.1.

Another alternative is the *Stratal OT* model proposed by Kiparsky (2008), which is effectively a pared down, more powerful version of Lexical Phonology, but this approach too must specify stratum-specific constraint rerankings.

restructuring. However, I will show that, despite these different treatments, both cases actually result from the same processes, and should be explained in a unified manner. Consequently, I will argue for a return to a more standard understanding of OT, and will show that the alternations present in each language can be accounted for by means of a single ranking of constraints, with no need for stratum-specific FAITH rerankings. Instead, I propose to account for non-productive alternations by updating the underlying form of the lexical items in question to reflect historical phonological change. This is an enhancement Optimality Theoretic analyses have long been in need of: lexical representation must be a vital part of a speaker's knowledge about their language, and OT needs access to a mechanism by which these representations can be updated to reflect diachronic change[2], and a better idea of exactly what information is transmitted between generations of speakers.

I will show that accounting for these non-productive alternations within the lexicon in this fashion frees up the phonology to better account for generalizations present in the synchronic data that are lost when each stratum[3] is treated individually. Furthermore, lexical updating eases the computational load on the speaker, as it no longer necessitates simultaneous evaluation of multiple constraint rankings. In addition, I show that updating underlying representations solves some problems of opacity, and suggests a more plausible view of learnability. Finally, lexical updating of this nature has widespread implications for modern approaches to phonology, and necessitates rethinking the Morphemic Principle and the importance of lexical representation in general within Optimality Theory.

The paper is organized as follows: In §2, I introduce the Japanese stratal data as presented by Itô & Mester (1993) and give a brief overview of the CP model and its account for these data. In §3 I bring forward additional Japanese data not capturable by the CP model and suggest a new approach to account for all of the data without resorting to FAITH reranking. §4 presents data for the distribution of voiced and unvoiced fricatives throughout the attested history of English, while §5 details the account of the English data within the CP model. In §6 I present my account of the English fricative data, which demonstrates the advantages of a single constraint ranking over multiple rankings of FAITH. Finally, §7 proposes a new method for determining this single synchronic ranking of phonological constraints through loanword adaptation and word formation processes.

2 Japanese Lexical Strata and the *Core-Periphery* Analysis

2.1 The Data

According to Itô & Mester (1993), Japanese can be divided into four distict strata: native, established Chinese loans, assimilated foreign words, and unassimilated foreign words. The native

[2]Throughout the paper, I adopt the common view of phonological change propounded by, among others, Jacobs (1995) and Anttila & Cho (1998), in which historical phonological change results in constraint reranking. During this process of constraint reranking, it is likely that there is a period of time in which the affected constraints are unranked relative to each other, resulting in temporary free variation.

[3]My theory moves away from the idea of multiple phonological strata that require evaluation of multiple constraint rankings synchronically within a single language. However, I retain the notion of the strata proposed in Ito and Mester as a descriptive tool describing the groupings of surface phonotactics resulting from forms stored at different stages throughout the history of a language. I leave open the possibility that other phenomena may require parallel evaluation of multiple constraint rankings synchronically, but for the historical data I treat here, I maintain that this is not the case.

stratum, also called the Yamato stratum, contains the lexical items present in the language from the earliest recorded Old Japanese. Most verbs, adjectives, and grammatical function words are members of this stratum, along with core nominals like colors, animals, and body parts. In Itô and Mester's analysis, the Yamato stratum is characterized by surface adherence to all four of the stratum-defining constraint sets in their analysis, listed below:

(1)

a. SyllStruc:	Prevents complex onsets and codas, as well as limiting codas to segments without place
b. NoVoicedGem (No-DD):	No voiced obstruent geminates (*bb, etc.)
c. NoVoicelessLab (No-P):	No singleton-p: prevents nongeminate [p]
d. NoNas Voiceless (No-NT):	Postnasal obstruents must be voiced (*nt, etc.)

Notably, the Yamato stratum is the only stratum to obey NoNas Voiceless (No-NT) in addition to the other three constraints above, which puts it at the "core" of Itô and Mester's Core-Periphery Model, described in the following subsection.

The established loan (Sino-Japanese (SJ)) stratum is the second oldest stratum in Japanese, being composed of lexical items borrowed from various Middle Chinese dialects as early as the second half of the first millennium CE. These borrowings comprise a large portion of modern Japanese vocabulary, and mostly denote abstract concepts. According to Crawford (2009), these words are composed of mono- or bisyllabic roots that each correspond to a single Chinese character, making them easily recognizable in Japanese orthography. The Sino-Japanese forms obey the first three constraints in (1) above, but are free to violate the No-NT constraint obeyed by Yamato items.

The third and fourth strata in Itô and Mester's model, the assimilated and unassimilated loans, are more recent foreign borrowings, mostly from western languages, starting in the 16th century. Neither stratum obeys the No-NT and No-P constraints obeyed by the Yamato and Sino-Japanese strata, putting them both on the "periphery" of the Japanese lexicon. The difference between the two, according to Itô and Mester, is that the assimilated loans obey the third constraint in (1), No-DD, whereas the only constraint set obeyed by unassimilated foreign loans are the SyllStruc constraints.

The behavior of the four strata related to the constraints in (1) is shown in the table below, reproduced from (Itô & Mester 2004: 557):

(2)

	SyllStruc	No-DD	No-P	No-NT
Yamato	✓	✓	✓	✓
Sino-Japanese	✓	✓	✓	violated
Assimilated Foreign	✓	✓	violated	violated
Unassimilated Foreign	✓	violated	violated	violated

Note that the organization of the hierarchy corresponds to the age of the strata, with strata borrowed progressively later violating progressively more constraints. This phenomenon will be instrumental in the lexical update analysis I develop later.

2.2 The *Core-Periphery* Model

Itô and Mester's *Core-Periphery* model (1995) is a hierarchical arrangement of lexical strata, where "the relevant structural organization of the lexicon is set inclusion, leading from the innermost lexical core Lex^0 to the most inclusive set $\text{Lex}^{\max}$ comprising all lexical items" (Itô & Mester 2004: 553). This idea is based on Kiparsky's (1973) observation that lexical stratification is gradual and hierarchical, with "exceptions to one rule always being exceptions to another rule, but not vice versa" (20). To put this generalization into practice in their model, Itô and Mester require that a single ranking of constraints apply to every stratum of a language's lexicon, with the caveat that FAITH will rank lowest in the core stratum, but will be progressively higher ranked as one moves out through the strata toward the periphery of the language's lexicon. This reranking of FAITH by stratum ensures that the hierarchical stratification noted by Kiparsky is maintained, and that the output forms present in the data are correctly generated. Thus Itô and Mester elegantly account for the differences seen between strata, while maintaining a strict single ordering of constraints (outside of FAITH, of course).

This approach is demonstrated below, in which we see two separate lexical items with an identical underlying form, /pan/, resulting in two different surface forms since they belong to two different strata. The assimilated foreign loan stratum values FAITH over NO-P, resulting in the more faithful surface form [pan], while the Sino-Japanese loan stratum values NO-P over NO-PFAITH, resulting in the surface form [han]. Note how the stratum-specific rankings of FAITH alone are sufficient to generate the correct surface form for each[4].

(3)

/pan/	NO-DD	FAITH/ Assimilated	NO-P	FAITH/ Sino-Japanese	NO-NT
'bread' ☞[pan]			*		
Assimilated Foreign [han]		*!			
'group' [pan]			*!		
Sino-Japanese ☞[han]				*	

The cost of this elegance is the multiple rankings of FAITH which put a greater load on production processing, as speakers must now choose the correct ranking of phonological constraints to apply to each lexical item as they produce an utterance. This model places an additional load on the lexicon, as there must be some way of tagging which lexical items are in which stratum to ensure that the correct FAITH ranking is applied.

In the following section, I will take a detailed look at Itô and Mester's data for each stratum. Though the *Core-Periphery* analysis presented above tends to generate the correct surface forms, I will show that multiple exceptions to their strata exist, and that lexical updating accounts not only for their original data, but for these exceptions as well. An added benefit of my model is the lack of any additional processing cost, as it requires only one constraint ranking in a language at a given time, with no reordering of FAITH constraints necessary and no stratum-tagging in the lexicon. The cost of my analysis is the necessity of updating these underlying forms to account for

[4]So that both forms can be presented in the same tableau, I use "FAITH/Assimilated" to represent the position of FAITH in the Assimilated stratum constraint ranking, and "FAITH/Sino-Japanese" to represent FAITH's position in the Sino-Japanese constraint ranking. This is not intended to indicate that two different FAITH constraints exist in the same constraint ranking.

alternations attributed to the synchronic phonology by the CP model, but recall that their model must also rely on the lexicon to tag which lexical items are in which stratum. Further, I will show that the additional lexical storage I require is motivated by diachronic phonological change. The data and analyses presented below will demonstrate that my lexical approach results in the more natural and desired outcome.

3 Exceptions to the CP Model, and an Alternative

3.1 The [h]/[p] Alternation

One puzzle of modern Japanese phonology is how to account for the [h]/[p] alternation seen in the Yamato and Sino-Japanese lexical strata. Old Japanese, /p/ ultimately became [b] after a nasal, geminate [pp] at morpheme boundaries, [ɸ] before [u], and [h] elsewhere[5]. These alternations are widespread in the modern language, and are seen clearly in verbal compounds like *hip-paru* 'pull strongly' (from **pik*-[6] 'pull' and **paru* 'stretch'), and in number+item counter compounds. The modern pronunciation of compounds formed with the counter **pon* 'cylindrical object' are shown below. Note the three different modern realizations of the **pon* morpheme.

(4)

Modern Compound Pronunciation	Number Morpheme	Counter Morpheme	Meaning
ip-pon	ichi 'one'	pon	'one cylindrical object'
ni-hon	ni 'two'	pon	'two cylindrical objects'
san-bon	san 'three'	pon	'three cylindrical objects'

Ito and Mester provide a straightforward account for these data with their constraint against nongeminate [p], No-P, that ranks above Faith in the Yamato and Sino-Japanese strata, but below Faith in the Assimilated and Unassimilated foreign strata, which accounts for the majority of the data. However, there is another counter from the Yamato period, **pun* 'minute', which, though it used to fully mirror the [h]/[p] alternation described for **pon*, has recently begun to violate No-P in fluent speech for some speakers, in spite of Ito and Mester's stratal requirements. Instead of producing the three modern realizations of **p* seen above, speakers have begun to generalize [p] throughout the paradigm:

(5)

Expected Compound Pronunciation	**New Compound Pronunciation**	Number Morpheme	Counter Morpheme	Meaning
ip-pun	**ip-pun**	ichi 'one'	pun	'one minute'
ni-ɸun	**ni-pun**	ni 'two'	pun	'two minutes'
san-bun	**san-pun**	san 'three'	pun	'three minutes'

[5]The road by which they got there was a bit more complicated: /p/ was weakened to [ɸ] in most environments. Word-initially, [ɸ] then became [h], except before [u], where it remained [ɸ]. Intervocalically, [ɸ] became [w] and was later deleted, except before [a] and [u] (Shibatani 1990: 167). Geminate [pp] generated from original Old Japanese [p] at morpheme boundaries remained unchanged.

[6]My use of asterisks when citing morphemes/compounds indicates that the form given is the oldest extant form of the morpheme, before the application of the later sound laws in question. This is meant to distinguish original underlying forms from what I will be positing as the current underlying forms resulting from lexical updating.

The counter **pun* is part of the Sino-Japanese stratum, so it must obey NO-P according to the CP model. Violations of NO-P should only be seen in the strata further toward the periphery, namely the assimilated and unassimilated Western borrowings. Given the nature of the framework proposed by Itô and Mester, in which more "nativized" lexical items are closer to the core of the lexicon and less nativized items toward the periphery, it makes sense that, as lexical items are produced more over time by speakers, they should correspondingly become more nativized and move toward the core of the lexicon, as noted by Crawford (2009). Here, however, we see the opposite movement happening with *pun*, as its violation of the NO-P constraint effectively moves it toward the periphery of the lexicon. The CP model has no mechanism by which to motivate this behavior.

The process active in the case of **pun* above is paradigm levelling, a common form of analogy. The question is, why do we see analogy violating a constraint so close to the core of the Japanese lexicon in favor of a segment sequence that should only occur on the periphery? As Kiparsky (2012) states, "analogical change is grammar optimization, the elimination of unmotivated grammatical complexity or idiosyncrasy" (p. 21). If this is correct, then the [h]/[p] alternation being neutralized by analogy here must be complexity that is not motivated by the grammatical processes currently active in Japanese. In other words, if this [h]/[p] alternation constituted unnecessary complexity, then it is unlikely that it was the result of a synchronic constraint interaction. Rather, I argue on this basis that the constraint NO-P has been deranked below FAITH across the board in modern Japanese, and that all [h]/[p] alternation occurrences are lexically stored forms that date back to when NO-P was ranked above FAITH. This means that the forms *ippun*, *niɸun*, *sanbun* had been lexically stored as single units. Consequently, the analogy seen above is the elimination of this no-longer-motivated alternation from the Japanese lexicon.

What does this mean for lexical items like *hipparu* 'pull strongly' and the difference between *pan* 'bread' and *han* 'group' above? Let's look a bit more closely at the history of the [h]/[p] alternation and see what it has to say about these alternations.

As mentioned above, the sound was originally realized as [p] in Old Japanese, indicating a low ranking of NO-P at this time, but according to Frellesvig (2010: 204), by the appearance of the first European sources during the Late Middle Japanese period (mid 16th century) the sound had already become [ɸ] or [f] morpheme-initially, as recorded by Portuguese missionaries in their transcriptions. For example, Old Japanese *pana* 'flower' was transcribed as *fana*, and *pito* 'person' as *fito*. So, sometime during the intervening eight hundred or so years, the sound had lost its occlusion and become a fricative, though retaining its [labial] feature. Recall that geminate [pp] was maintained at certain morpheme boundaries, creating an alternation between the two labial sounds, [ɸ] initially and [pp] medially. There is, then, good evidence that during the Middle Japanese period NO-P became more highly ranked, constituting a sound change resulting in a lenition of labial occlusion word-initially, effectively eliminating initial [p] from the language. Since modern Sino-Japanese lexical items also exhibit the [h]/[p] alternation, the sound change must have taken place after, or been active during, the widespread adoption of Chinese morphemes in the Early Middle Japanese period.

Why is this important? At some point during Middle Japanese, crucially, [ɸ] and [pp] were both clearly allophonic variants of /p/, occurring in complementary distribution and possessing a [labial] feature. In the mid- to late-16th century, however, we see the appearance of the Portuguese loanword [pan] 'bread', without undergoing modification to [ɸan]. This indicates that either before or during the borrowing of *pan*, the constraint against initial [p] had become deranked in Japanese,

allowing [p] to be borrowed as-is. As a result, we can see that the contrast between [ɸ] and [p] had become phonemic. Thus, since the Yamato and Sino-Japanese lexical items originally beginning with [p], such as SJ *pan* 'group', did not merge with the new p-initial borrowings, the most likely conclusion is that speakers *had already changed the underlying form* of their entire original p-initial lexicon from /p/ to /ɸ/. Later, around the year 1800, /ɸ/ further dissimilated from /p/ through a subsequent sound change to the modern result, /h/. I argue, therefore, that the underlying form of words beginning with [p] in Old Japanese have as their underlying form in modern Japanese either /ɸ/ or /h/, and foreign words beginning with [p] borrowed after the 16th century have the underlying form /p/.

Based on the above data, the OT analysis of *pan* 'bread' and *han* 'group' becomes trivial, with only one set of constraint rankings, as seen below:

(6)

	SyllStruc	Faith	No-P
/pan/ 'bread' ☞[pan]			*
Assimilated Foreign [han]		*!	
/han/ 'group' [pan]		*!	
Sino-Japanese ☞[han]			*

Here 'bread' and 'group' have different underlying forms for reasons explained above, and No-P has been deranked, so FAITH alone is enough to generate the correct surface forms.

This analysis also allows for the analogy we saw in the suffix **pun* 'minute' in (5) above. With the prohibition against [p] effectively no longer present in the language, the lexicon is free to simplify the paradigm by eliminating the no-longer-necessary allomorphic variants, each instantiation of which now had to be stored separately in the lexicon. Why do we not also see analogy in other [h]-initial suffixes then, like the paradigm of **pon* shown in (4) above? As noted by Sturtevant (1947) in his famous paradox, "Sound change is regular, but produces irregularity. Analogy is irregular, but produces regularity." So, though we can predict the classes that analogy will act on, we cannot predict the exact lexical items that will be affected by it. I do, however, believe that we will see further levelling of the [h]/[p] alternation in the near future.

It should be noted that my analysis necessitates arguing that the underlying forms of compound root verbs like *hip-paru* "pull strongly" (lit. "pull-stretch") be stored in their entirety, i.e. as /hipparu/, distinct from the original root morpheme of the second half of the compound, /haru/ 'stretch'. This is not very problematic, however, as compound root verbs like these are a closed class; the conditions for their formation in the Middle Japanese period are no longer present in the modern language. In fact, *-pparu* specifically has become reanalyzed in the modern language as a verbal suffix meaning "do X strongly". This semantic disassociation from its root *haru* 'stretch' is not unexpected if *-pparu* now has its own lexical entry separate from *haru*.

The [h]/[p] data seen in this section demonstrates that the analysis I propose can account for the alternations seen in Itô and Mester's data, as well as for the exceptions to their data presented above, with a single synchronic ranking of constraints motivated by Japanese sound changes and borrowings throughout history. This elegance comes at the expense of a heavier reliance on the lexicon in closed word classes, in that multiple versions of some morphemes must be separately stored, but this is itself motivated by the historical behavior of the data, as we have seen. Before

we move on to the next of Itô and Mester's Japanese constraints, No-NT, I will make a brief detour to more explicitly discuss the implications of my analysis above on the morphemic principle.

3.1.1 Implications for the Morphemic Principle

In the strictest and most traditional understanding of the morphemic principle, each morpheme in a language has exactly one corresponding underlying form stored in the mental lexicon, and the various surface realizations of this morpheme result from the regular word-building process of the language and the regular phonological changes that accompany them. The support for this principle stems from the understandable desire to keep unnecessary redundancy out of our language models, and to minimize the reliance of those models on lexical storage, but the need to revise this strong version of the morphemic principle to account for phenomena like partial suppletion has long been recognized.

In proposing that *ippun*, *niɸun*, and *sanbun* be stored separately in the lexicon, I am effectively proposing that three different underlying forms of **pun* be stored in these strings, in violation of the "strong version" of the morphemic principle. As such, I propose weakening the morphemic principle to allow separate storage when the allomorphs in question are no longer products of phonological processes active in the language.

As discussed above, I argue that there is an absolute (non-stratum dependent) ranking of No-P below Faith in the modern Japanese language, and that the various allomorphs of *pun* are lexical remnants of the era of Japanese history when the opposite ranking held between these two constraints. These alternations in the modern language are therefore *lexical*, and are no longer *phonological*, and thus fall outside the domain of this weaker version of the morphemic principle.

Storage of these multiple forms does not come without cost to the system, however, as we see in the analogical levelling of *pun*. If multiple versions of a single morpheme are stored separately in the lexicon, we would assume that there must be accompanying storage costs and processing costs from accessing these additional forms. In the case that each form does not dissociate from its sisters by some means (i.e. grammaticalization or a different semantics), then storage of these multiple forms is ultimately a duplication of effort that creates unnecessary complexity for the system. This puts pressure on the system to simplify, resulting in the levelling seen in *pun*.

On the other hand, the semantic dissimilation seen in *haru* versus *-pparu* indicates that the additional stored forms of a morpheme may become stable, separate morphemes of their own. Effectively, storage of multiple forms of the same morpheme creates pressure in the system to either find a use for the additional complexity by reassigning each form a separate role in the system or to eliminate the complexity entirely through processes like analogical levelling.

Now let's move on to the evidence presented by Itô and Mester for another of their constraints, No-NT, in order to see if the lexical update analysis presented here can better account for this data as well.

3.2 Exceptions to No-NT

As noted above, No-NT is the constraint obeyed only by the Yamato stratum, and violated by the other three strata. Itô and Mester illustrate this constraint with the gerundive and past tense

endings of Yamato verbs, /-te/ and /-ta/ respectively, which become voiced following a root with a final voiced segment (which always surfaces as a manifestation of the placeless underlying nasal, /N/). This correspondence is seen below:

(7)

Root	**Gerundive**	**Past**
sin- 'die'	*sin-de*	*sin-da*
yom- 'read'	*yon-de*	*yon-da*
tob- 'fly'	*ton-de*	*ton-da*
mi- 'see'	*mi-te*	*mi-ta*
kaw- 'buy'	*kat-te*	*kat-ta*

In the Sino-Japanese stratum, on the other hand, nasal plus voiceless obstruent combinations are quite common, seen in words like *hantai* 'opposite' and *sinpai* 'worry'. Itô and Mester's ranking of No-NT over Faith in the Yamato stratum but below it in the SJ stratum effectively generates the desired forms:

(8)

	Faith/ SJ	No-NT	Faith/ Yamato
/shin-ta/ 'die' [shinta]		*!	
Yamato ☞[shinda]			*
/hantai/ 'opposite' ☞[hantai]		*	
Sino-Japanese [handai]	*!		

However, Rice (1997) provides a list of Yamato words containing outright violations of No-NT, including examples like *intiki* 'trickery' and *anta* 'you'. Crawford (2009) points out that *anta* is particularly interesting as it derives from *anata* via syncope, and coexists with the original form. In effect, this means that either the No-NT constraint did not act as predicted for this Yamato form, or that this form has somehow moved from the core toward the periphery, as it now patterns with the Sino-Japanese stratum. Either way, this poses a problem for Itô and Mester. If the former, then their constraints have unexplained exceptions, and if the latter, then again we see that their theory has no mechanism to motivate movement of lexical items toward the periphery of the lexicon. Itô & Mester (1995) call exceptions like these "undoubtedly native, but peripheral" (p. 830), but provide no explanation for their behavior.

With lexical updating, however, the analysis is straightforward. At the time Sino-Japanese words with NT sequences were borrowed, there could not have been a highly ranked constraint against this sequence, since it was borrowed with no modification. In Old Japanese, however, we see that no words with NT sequences surface at all, indicating that there was likely a highly ranked constraint preventing these sequences at the time. Children acquiring Japanese during the Old Japanese period would never be exposed to this sequence on the surface, and would store all nasal plus obstruent sequences as voiced underlyingly, whether or not a prior generation had possessed underlying voiceless obstruents following nasals. By the time that the No-NT constraint was demoted, before the borrowing of the Sino-Japanese loans, nasal plus obstruent clusters would have been universally stored as voiced underlyingly, and NT clusters would have been effectively eliminated from the language. These underlying ND sequences would remain stable diachronically, as ND sequences are the less marked forms. This explains the rarity of the exceptions to the Yamato stratum, as they

may only result from subsequent grammatical processes, such as the syncope we see in *anta* above.[7]

What about the past tense and gerundive data in (7) then? Once the constraint was demoted, why didn't the endings become *-ta* and *-te* after the nasals? In addition to the markedness argument above, this can also be explained by an analogical relationship, namely paradigm uniformity. Yamato-type verbs are a closed class in Japanese; after the Sino-Japanese borrowings, new verbs were (and still are) created by compounding a noun with the light verb *suru*. If the Yamato voiced endings were to revert to their voiceless variants through analogy with the non-nasal-final verbs, this would either have to happen spontaneously and simultaneously across the entire Yamato verb class, which is not very likely, or individual verbs would have to adopt the voiceless suffixes one at a time. The latter is improbable due to the desire of speakers to have regular paradigms whenever possible, so as soon as one verb adopted a voiceless suffix, paradigm uniformity with the other root-final nasals would immediately level it back out in favor of the voiced suffixes. I therefore argue, based on these observations, that NO-NT is currently not a highly ranked constraint in the Japanese language, and that the gerundive and simple past tense of Yamato-type verbs with roots ending in a voiced stop (again, a relatively small, closed class) are stored in the lexicon individually, with paradigm uniformity preventing analogical change.

In this section we have seen that the boundaries of the strata proposed by Itô and Mester, though mostly consistent, are not without exception. The Core-Periphery model has no provision to account for these exceptions, since it requires that all items in the modern language from a given stratum conform to the corresponding constraint ranking synchronically. In the model I propose, however, the strata are defined in terms of word origin alone, with their phonological similarities and differences being the product of their sources and of the lexical entries resulting diachronically from the constraint ranking of Japanese at the time of their borrowing/formation (which may no longer be the ranking of the language today). Thus I would predict that many apparent synchronic phonological alternations may in fact be diachronic remnants of previous synchronic processes, which are made apparent when new forms crop up that freely violate expected constraint interactions. Since many of the alternations previously handled by multiple strata of constraint rankings in the CP model are now handled directly by the lexicon, my analysis has no trouble accounting for the exceptions to Itô and Mester's strata, as they are merely examples that show which constraints are no longer active.

In the next subsection I address another of Itô and Mester's constraints, NO-DD, and show that the loanword adaptation data indicates that the NO-DD constraint is also no longer ranked above FAITH in modern Japanese.

[7] A more formal model proposed to account for acquisition effects on underlying form as discussed in this paragraph is the *Input Optimization* model of Bermúdez-Otero (2006). It requires that:

1. Input representations must be Pareto-optimal.
2. An input representation is Pareto-optimal if, and only if, it has no competitor that (i) generates **all** output alternants no less efficiently and (ii) generates **some** output alternant more efficiently.

This version of Input Optimization ensures that the input forms stored by children in acquisition correspond closely to the constraint ranking present in the language. For my purposes this model mostly generates acceptable updated underlying forms; I am however hesitant to fully adopt it here due to the extreme restrictions it places on the lexicon. Bermúdez-Otero does not go so far as to weaken or reject the morphemic principle, which makes my analysis incompatible with his Input Optimization model as formulated. That said, I do believe that it constitutes a step in the right direction, and that it could be adapted to the analysis I present here with minimal changes.

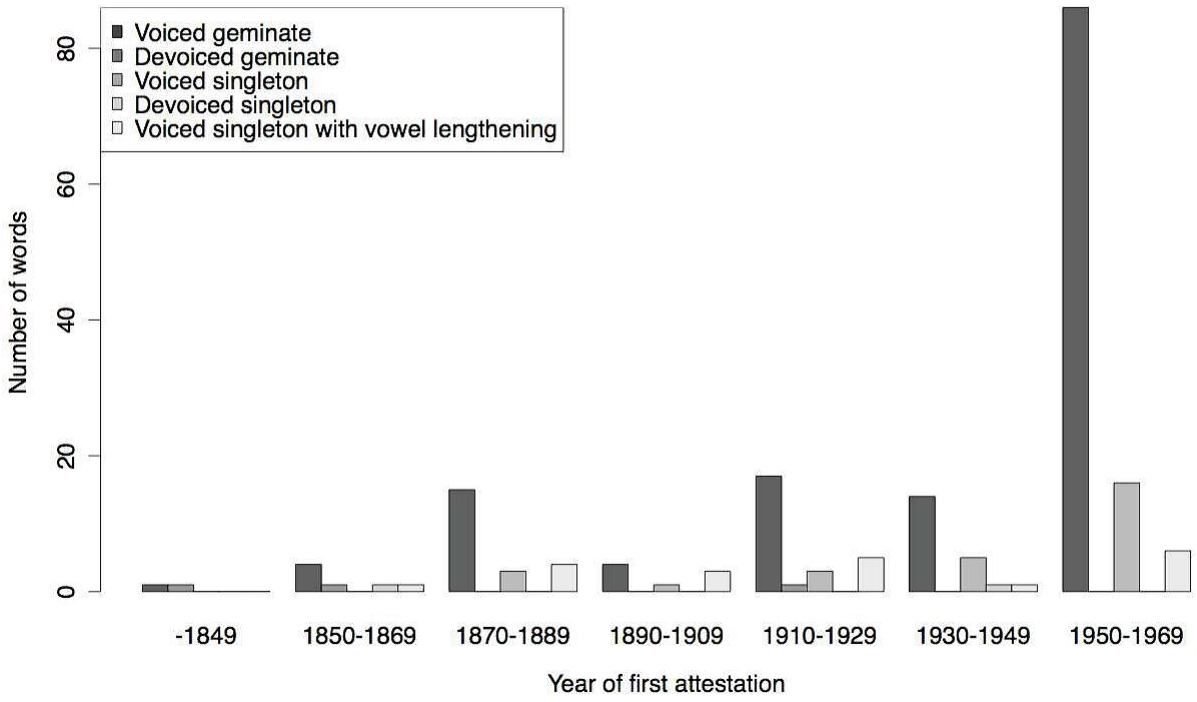
3.3 Exceptions to No-DD

According to Itô and Mester's analysis, borrowings from English ending with a voiced obstruent are adapted with a geminate obstruent that is either voiced or voiceless depending on whether the word is an unassimilated or assimilated borrowing, respectively. Unassimilated loans rank No-DD lower than Faith, while assimilated loans rank it higher. This analysis is demonstrated below, with the unassimilated *bed* surfacing as *beddo* and the assimilated *bag* surfacing as *bakku*.

(9)

	SyllStruc	Faith/ Unassimilated	No-DD	Faith/ Assimilated
[bag]	*!			
/bed/ 'bed' ☞[beddo]			*	
Unassimilated [betto]		*!		
[bag]	*!			
/bag/ 'bag' [baggu]			*!	
Assimilated ☞[bakku]				*

Crawford (2009), however, shows that these borrowings are far more complex than they first seem. There are in fact five different possible adaptation mechanisms for English borrowings with a final voiced consonant: voiced geminates, devoiced geminates, voiced singletons, devoiced singletons, and a lengthened vowel before a voiced singleton. The frequency of adaptation by each mechanism over time is shown below in (10), taken from Crawford (2009: 60), based on data from Arakawa (1977).



As we can see, since the earliest attestation of these types of borrowings, geminating the voiced stop has been consistently the most popular mechanism for adapting them to Japanese pronunciation. Crawford states the following about the data:

> "Among the entire set of words collected from Arakawa, the only ones which are listed with three or more attestations with a voiceless geminate are *betto* 'bed', *handobakku* 'handbag', *operapakku* 'operabag', and *burudokku* 'bulldog'. Of these, both *bed* and *operabag* are also attested with alternate forms, *beddo* and *operabaggu*, that have a voiced geminate." (p. 61)

He also mentions that *bed* may have even come from German or Dutch, both of which end in a voiceless stop.

Given the complexity of the borrowing data in the chart above and the paucity of the devoiced geminate data, NO-DD seems an odd candidate for a constraint that differentiates recent loanword strata. Also notable is the fact that the words which do show the devoiced gemination characteristic of Itô and Mester's assimilated foreign stratum were originally borrowed with that pronunciation, and that none of the words initially borrowed with voiced geminates have shown "nativization" movement into the Assimilated Loans stratum.

It seems more likely that these different adaptation mechanisms are due to different constraint rankings in the dialects or even idiolects of the original borrowers, and that different forms of borrowed terms diffused unequally through the rest of the language. This is made more plausible by data from Lovins (1975), who notes that many of these borrowings have doublets which use different adaptation mechanisms (such as *gyagu* and *gyaggu* for 'gag, joke' and *nobbu* and *nobu* for 'knob'). Regardless, the most important observation to make from the standpoint of the model I advocate in this paper is that from the earliest attestations of these voiced-final borrowings, a voiced geminate has been the preferred method of adaptation. So, though Japanese may have at one point had a highly ranked NO-DD constraint (as indicated by Yamato forms like *ason-da* from *asob-* 'play' and the past tense suffix *-ta*), the English borrowing data clearly indicates that this constraint was no longer highly ranked in the language by the 1850s. Also, whatever the reason for the existence of these multiple borrowing mechanisms, it seems fairly clear that once successfully borrowed and lexicalized, these alternations are governed not by separate rankings of phonological constraints, but by these lexical items possessing distinct underlying forms.

3.4 Midpoint Summary

I have introduced the *Core-Periphery* model of Itô and Mester, and have shown using Japanese data that this model is unable to sufficiently describe the behavior of lexical strata in Japanese. Instead, I have proposed that updating the underlying forms of lexical items to reflect historical sound change both accounts for the exceptions to the strata proposed by Itô and Mester, and eliminates the necessity of positing multiple rankings of FAITH to account for these strata. I have shown that the exceptions to these strata are often the work of analogy, and that Itô and Mester have no explanation for these analogical processes. In response to the necessity of positing multiple underlying forms for individual morphemes, I have proposed a weakening of the morphemic principle, which restricts its application to productive phonological allomorphy only, and allows for lexical allomorphy.

I will now turn to another case study, the behavior of fricative strata in modern English. These lexical items have been looked at from a historical perspective, but not, to my knowledge, from a

synchronic phonological perspective. I will show that, though the Japanese data above has been codified as a phonological problem and the English fricative data below as a lexical problem, they are actually the same[8]. Accordingly, I propose the same account for the English data that I proposed for the Japanese data: a synchronic phonological analysis that takes into account the reality of lexical restructuring. This constitutes a unified account for both phenomena that is somewhere in between the traditional analyses of these two problems.

To parallel the Japanese analyses in the first half of the paper, I will first analyze the English data within the *Core-Periphery* model before presenting my own analysis, in order to better highlight the differences between the two.

4 Fricative Strata in English

In modern English, /f/, /s/, and /θ/ all contrast with their voiced counterparts, /v/, /z/, and /ð/ word-initially, medially, and finally. However, this was not always the case: in Old English these pairs were allophones, with the voiceless forms appearing initially and finally, and the voiced forms appearing medially between voiced segments. Geminate voiceless fricatives, which are no longer present in modern English, could appear medially and finally. The following chart, reproduced from Lass (1999), shows the distribution as of Old English.

(10) **English fricative distribution before the 12th century**

		Foot-initial	*Foot-medial*	*Final*
Labial	Short (vl)	f	-	f
	Short (vd)	-	v	-
	Long	-	fː	fː
Dental	Short (vl)	θ	-	θ
	Short (vd)	-	ð	-
	Long	-	θː	θː
Alveolar	Short (vl)	s	-	s
	Short (vd)	-	z	-
	Long	-	sː	sː

Then, according to Lass, during the 12th century word-final /ə/ was deleted, leaving many now-final voiced fricatives in contrastive position with final voiceless fricatives. Thus, /v/ in words like /driːv/ 'drive' contrasts with the /f/ in /hlaf/ 'bread', /ð/ in /baːð/ 'bathe' contrasts with /baθ/ 'bath',

[8]The question of why this difference in approach exists at all is an interesting one. Japanese orthography may potentially play some role, as it is uniquely suited to both overtly differentiating historical strata and preserving morphemic associations that have shown drastic semantic shifts. Japanese's use of different scripts for native/Sino-Japanese words as opposed to more recent borrowings keeps the differences between strata fresh on speakers' minds. Also, continuing to use the same kanji for different words in the modern language that historically stem from the same original morpheme (such as the aforementioned *haru* versus its semantically differentiated sister *pparu*, when both still use the same character) may contribute to keeping these similar origins more readily apparent to speakers than corresponding English spellings. Consequently, whereas English speakers may view their language in a more diachronic fashion, Japanese speakers might instead be more likely view their language as multiple disparate systems all coexisting synchronically.

and /z/ in /nɔːz/ 'nose' contrasts with the /s/ in /hus/ 'house'. This left the distribution as follows:

(11) **English fricative distribution during the 12th century**

		Foot-initial	*Foot-medial*	*Final*
Labial	Short (vl)	f	-	f
	Short (vd)	-	v	v
	Long	-	fː	fː
Dental	Short (vl)	θ	-	θ
	Short (vd)	-	ð	ð
	Long	-	θː	θː
Alveolar	Short (vl)	s	-	s
	Short (vd)	-	z	z
	Long	-	sː	sː

At around the same time, following the Norman invasion, central English began to successfully borrow words with initial [v] and [z] from multiple sources. According to Minkova (2014), Latin and Old French provided the majority of [v]-initial forms, while most [z]-initial forms like *zephyr* came from Greek. From Old French came words such as the ancestors of *veal* and *zeal*, while some words with initial [v] like *vat* and *vixen* were also borrowed from the southern dialects of English itself, where initial fricatives became voiced.

Minkova notes that the success of these borrowings is noteworthy, as earlier [v]-initial borrowings "were assimilated early to the native template of initial voicelessness" (92) as [f], as seen in OE [fers] 'verse' and [fann] 'fan', from Vulgar Latin [versus] and [vannus].

Initial [ð], however, came from an entirely different source. In the 14th century, unstressed function words with initial /θ/ became voiced to [ð] when following a word with a final voiced segment. This change spread to all environments, and to a few other commonly occurring lexical items, giving English its very small class of ð-initial words like *the*, *then*, *there*, and *that*. The effect of these similar yet separate changes on the distribution is as follows:

(12) **The effect of voiced-initial words in 14th century English**

		Foot-initial	*Foot-medial*	*Final*
Labial	Short (vl)	f	-	f
	Short (vd)	v	v	v
	Long	-	fː	fː
Dental	Short (vl)	θ	-	θ
	Short (vd)	ð	ð	ð
	Long	-	θː	θː
Alveolar	Short (vl)	s	-	s
	Short (vd)	z	z	z
	Long	-	sː	sː

One final process was going on during this time: starting around 1200 in the north and spreading southward, geminate consonants lost their gemination. This ended consonantal length distinction in English and resulted in the merger of geminate and singleton fricatives in final position. Notably, this process placed singleton voiceless fricatives in contrast medially with their voiced counterparts. Examples of this process are seen in modern English *offer*, *this* (from *thessa*), and *kith* (from *cyþþu*).

The final result of all of these changes is the simpler and more symmetrical system below, where voiced and voiceless fricatives contrast in all positions.

(13) **Middle English voiced fricative distribution**

		Foot-initial	*Foot-medial*	*Final*
Labial	Short (vl)	f	f	f
	Short (vd)	v	v	v
Dental	Short (vl)	θ	θ	θ
	Short (vd)	ð	ð	ð
Alveolar	Short (vl)	s	s	s
	Short (vd)	z	z	z

4.1 [ʃ] and [ʒ]

The astute reader has probably noticed that Modern English has another pair of fricatives that haven't yet been mentioned here: [ʃ] and [ʒ]. They occur in all the positions that the other fricatives do (as in *shall*, *fish*, *fishes*, *vision*, and dialectal *genre* and *garage*), but their story follows a slightly different path than the fricatives discussed above.

[ʃ] was an internal development of English not present in Proto-Germanic (c.f. Gothic *fisks* "fish"), and developed as a result of palatalization of the [sk] cluster before front vowels and word-finally sometime during the early 10th century (Wayne Harbert, personal communication). That this was a late development is evidenced by the presence of metathesis in texts as late as the 9th century. If [sk] had already fused into one segment [ʃ], this metathesis wouldn't have occurred.

As a result of this palatization, we get our expected [ʃ] initially and finally, but, interestingly, we see no sign of voicing to [ʒ] medially. Harbert believes that this is due to the medial voicing rule in English simply no longer being active by this point, but I believe that there is another explanation. Note how, medially, in a word like genitive singular *fiskes* 'fish', the [s] forms the coda of the first syllable and the [k] the onset of the second.[9] I argue that, to preserve the second mora in the first syllable of *fisces*, [sk] developed into a geminate [ʃː], which acted as both coda and following onset, producing a new form [fiʃːes]. Consequently, just as with the other geminate fricatives discussed above, this geminate [ʃː] would remain voiceless medially. Word-initially, however, since the [sk] onset wouldn't contribute to syllable weight, the geminate would be free to immediately simplify to a singleton [ʃ][10]. Thus, the distribution of the palatal fricative before the Norman Invasion was as follows:

(14) **Pre-12th century distribution of [ʃ] and [ʒ]**

[9]This assumes that Old English had the constraint ranking *ComplexOnset>>NoCoda, which is reasonable considering Modern English syllabification.

[10]Further support for this analysis potentially comes from Middle English Open Syllable Lengthening (MEOSL) as discussed in Lahiri & Dresher (1999). In this process, stressed initial open syllables undergo lengthening under certain conditions. My analysis of words like *fisces*, in which I argue that the [sk] cluster became a geminate [ʃː], predicts that these words should not undergo MEOSL, as the first half of the geminate should act as the coda consonant. And, just as predicted, no forms with an applicable [sk] cluster appears in the exhaustive MEOSL list found in Minkova (1982).

			Foot-initial	*Foot-medial*	*Final*
	Short (vl)	Voiceless	ʃ	-	-
Palatal	Short (vd)	Voiced	-	-	-
	Long	Voiceless	-	ʃː	ʃː

Then, during the 12th century, as seen above with the other fricatives, geminate [ʃː] lost its gemination. Medial occurrences of [ʃ] were now singletons, but they did not yet have any [ʒ] to contrast with, as there were no native or loan sources of [ʒ] (as there were no earlier medial [ʃ] singletons to voice and French had not yet developed [ʒ]). Thus, the complete fricative chart as of 1400 looked as follows:

(15) **English fricative distribution by the end of the 14th century**

		Foot-initial	*Foot-medial*	*Final*
Labial	Short (vl)	f	f	f
	Short (vd)	v	v	v
Dental	Short (vl)	θ	θ	θ
	Short (vd)	ð	ð	ð
Alveolar	Short (vl)	s	s	s
	Short (vd)	z	z	z
Palatal	Short (vl)	ʃ	ʃ	ʃ
	Short (vd)	-	-	-

Finally, according to Dobson (1957), by the 17th century sound change had led to [sj] becoming [ʃ] in words like *facial* and *nation*, and, correspondingly, [zj] to [ʒ] in *usual* and *vision*. Dobson notes that grammarians from this period consider [ʒ] as a French sound (958), though this change originated within English and not through French borrowings. By the 20th century borrowings from French such as *genre* and *beige* had filled out the rest of the distribution, though it should be noted that in many dialects of English initial and final [ʒ] are instead pronounced [ʤ]. The final version of the fricative distribution chart in Modern English is as follows:

(16) **Modern English fricative distribution**

		Foot-initial	*Foot-medial*	*Final*
Labial	Short (vl)	f	f	f
	Short (vd)	v	v	v
Dental	Short (vl)	θ	θ	θ
	Short (vd)	ð	ð	ð
Alveolar	Short (vl)	s	s	s
	Short (vd)	z	z	z
Palatal	Short (vl)	ʃ	ʃ	ʃ
	Short (vd)	(ʒ)	ʒ	(ʒ)

5 A *Core-Periphery* Treatment of the English Fricative Data

Any complete descriptive analysis of English fricative data should account for all four of the changes described in Section 2 above, listed as follows: final [ə] deletion (Deletion), borrowing of initial [f] and [v] (Borrowing), prosodic development of initial [ð] (Initial ð), and Degemination.

I propose the following constraints to account for the data: *FinalSchwa prevents final [ə], and is the constraint that governs Deletion; *InitialLabiodental/AlveolarVoicedFricative(*InitialVZ)

prevents initial voiced [v] and [z], and governs Borrowing; Initial ð is governed by *InitθUnstr, which prevents initial [θ] in prosodically unstressed words; and *Gem governs Degemination by preventing geminate consonants.

I classify the data into two strata. The *core* stratum, designated "Native", is composed of all lexical items present in Old English before the adaptation of loanwords with initial voiced fricatives, and is contrastively characterized by obeying the *InitialVZ constraint. The *peripheral* stratum, designated "Loan", is characterized by the violation of *InitialVZ and the introduction of a stratum-specific high ranking of Faith to ensure the surfacing of underlying /v/ and /z/. This Loan stratum consists of the borrowings from French and the southern English dialects.

This stratum division is necessary due to the differing surface forms of underlying Latin and Old French initial /v/. The Latin borrowings are considered to have assimilated into the Native stratum for our purposes, since these borrowings do not show a surface contrast with the other members of Native. Note that contrasts created within a stratum due to sound change do not necessitate the creation of a new stratum. For example, words with [ð] resulting from the Faith constraint reranking are considered Native, since an initial [θ]/[ð] alternation is present on the surface within the original Native vocabulary in modern English. Similarly, words with the [ʃ]/[sk] alternation seen in *fish* (originally *fisk*) versus *ask* are all considered Native.

Table (17) below generates surface forms based on the constraint rankings of Old English as they existed before the Norman invasion:

(17)

		*InitialVZ	Faith	*Gem	*Finalə	*InitθUnstr
/draivə/ ☞	[draivə]				*	
Native	[draiv]		*!			
/offᵊ/ ☞	[offᵊ]			*		
Native	[ofᵊ]		*!			
/θɪs/ ☞	[θɪs]					*
Native	[ðɪs]		*!			
/væn/	[væn]	*!				
Native ☞	[fæn]		*			
Latin						
/fiʃʃes/ ☞	[fiʃʃes]			*		
Native	[fiʃes]		*!			

Then, during the transition from Old English to Modern English, the four changes described above, Deletion, Borrowing, Initial ð, and Degemination, occurred. To account for the results of these changes in the phonological system, I rerank the *Gem, *Finalə, and *InitθUnstr constraints more highly than Faith. This new reranking accounts for the data in the Native stratum after 1400, but a problem quickly becomes apparent when taking into consideration the borrowings from French and other English dialects such as "zeal" and "vat": since *InitialVZ still outranks Faith, /ziːl/ and /væt/ would surface as [siːl] and [fæt]. This is clearly an undesirable outcome. To correct the situation, the ranking of Faith in the Loan stratum must be above *InitialVZ to ensure surface [ziːl] and [væt]. Table (18) below demonstrates the effects of the rerankings in place by 1400, and, with this stratum-specific reranking of Faith, written below as Faith/Loan,

generates the correct modern surface forms.

(18)

			*Gem	*Finalə	Faith/*Loan*	*InitialVZ	*InitθUnstr	Faith
/draivə/		[draivə]		*!				
Native	☞	[draiv]						*
/offəˇ/		[offəˇ]	*!					
Native	☞	[ofəˇ]						*
/θɪs/		[θɪs]					*!	
Native	☞	[ðɪs]						*
/væn/		[væn]				*!		
Native	☞	[fæn]						*
Latin								
/fɪʃʃes/		[fɪʃʃes]	*!					
Native	☞	[fɪʃes]						*
/ziːl/	☞	[ziːl]				*		
Loan		[siːl]			*!			
/væt/	☞	[væt]				*		
Loan		[fæt]			*!			

So, we see that the *Core-Periphery* model can descriptively account for the fricative strata seen in modern English in addition to the Japanese data from the first half of the paper. Even with the benefits of Itô and Mester's model, however, I believe that an even more explanatorily adequate analysis is available. In the next section, I will critique the *Core-Periphery* model and show that, again, the lexical update approach offers an alternative that not only accounts for the data, but also captures generalizations missed by the *Core-Periphery* approach.

6 An Alternative Analysis: Updating Lexical Representations

As stated in earlier sections, allowing underlying representations to update allows a single ranking of constraints to account for alternations that otherwise require the inter-stratum constraint ranking differences exhibited by the *Core-Periphery* model. In keeping with this proposal, I argue that only one set of constraints is necessary to accurately describe the phonological processes active at any given time in Old, Middle, and Modern English, that no stratum-specific reranking of Faith is necessary, and that the very idea of "multiple strata", while descriptively and historically interesting, is unnecessary to account for the data given in §5. The surface alternations between Native vocabulary and loans from French and dialectal English which require separate strata in the Core-Periphery model, I instead attribute to differences in underlying representation that are simply maintained on the surface.

Due to perception studies such as Dupoux *et al.* (1999), in which perception of non-native strings by native speakers is heavily influenced by the phonotactic constraints of their native grammar, I argue that it is unlikely that borrowed words are accurately stored in the borrowers' lexicons as they are pronounced in the source language, especially when that underlying form would contain segments unpronounceable by speakers of the borrowing language. It seems far more likely that Old English speakers borrowed Latin [versus] with an underlying /f/ from the start than with an underlying sound they were unable to pronounce (or likely even distinguish at that time) due to the then-highly ranked *InitialVZ constraint (cf. Itô & Mester (2004) for similar Japanese examples). And even if the initial borrowers did borrow it with /v/, there quickly arises a learnability issue for

their children, who would hear only [f], and, with no other evidence at their disposal, would quickly adopt /f/ as their underlying representation. Thus, I maintain that the underlying forms of all new morphemes that entered the language during the Old English period were lexicalized according to the constraint ranking active at that time[11].

Then, almost a thousand years after these Latin borrowings, all the major changes described in Section 5 above were realized by different processes almost simultaneously. This is unlikely to be a coincidence; more probably, some systematic, foundational aspect of the English consonant system changed fundamentally. The generalizations about these changes are simple and straightforward: **initial and final voiced fricatives appeared** (though many different processes conspired to reveal this generalization), and **geminates degeminated**[12]. The constraint rerankings that made these changes possible allowed English speakers to distinguish voiced and voiceless fricatives in initial position, so borrowings with initial voiced fricatives could now be adapted as such from French and other English dialects freely.

The following constraint set accounts for the generalizations observed above. First, I collapse the separate constraints preventing initial and final voiced fricatives in the *Core-Periphery* model into a single constraint, *EdgeZ, in order to capture the generalization that all of these separate processes are merely different facets of the same phenomenon. Second, I borrow from the *Core-Periphery* analysis *Gem, *Finalə, and *InitθUnstr constraints to simplify geminates, motivate schwa-deletion, and voice unstressed /θ/[13], respectively. The tables below in (19) and (20) again reflect the constraint rankings before the Norman invasion and at around 1400, respectively:

(19) **Constraint ranking for Old English fricatives with lexical updating**

		*EdgeZ	Faith	*Gem	*Finalə	*InitθUnstr
/draivə/ ☞ [draivə]					*	
Native [draiv]	*!		*			
/offᵊ/ ☞ [offᵊ]				*		
Native [ofᵊ]			*!			
/θɪs/ ☞ [θɪs]						*
Native [ðɪs]	*!		*			
/fæn/ [væn]	*!		*			
Native ☞ [fæn] *Latin*						

(20) **Constraint ranking for Middle English fricatives with lexical updating**

[11]Note, however, that positing different underlying forms has no bearing on the question of whether there are constraints on the types of possible underlying forms. This is an argument in favor of increased recognition of the importance of underlying representations, and is not at all intended to be an argument for or against Richness of the Base. I am not asserting that Old English *could not* adopt an underlying /v/ from Latin [versus]; I am merely asserting that they *likely did not*.

[12]Also, notice how perfectly the filling out of the charts in §4 above harkens back to Clements (2003)'s Feature Economy principles: when inventory gaps appear, they will likely be filled. It's also interesting to see just how well the constraint rerankings conspire to fill exactly the missing gaps.

[13]Over time, as the change from initial θ to ð became dissociated from prosodic structure and became generalized for these lexical items in all positions, I believe their underlying forms would consequently shift from /θ/ to /ð/.

			*Gem	*Finalə	*InitθUnstr	Faith	*EdgeZ
/draivə/		[draivə]		*!			
Native	☞	[draiv]				*	*
/offᵊ/		[offᵊ]	*!				
Native	☞	[ofᵊ]				*	
/θɪs/		[θɪs]			*!		
Native	☞	[ðɪs]				*	*
/fæn/		[væn]				*!	*
Native *Latin*	☞	[fæn]					
/ziːl/	☞	[ziːl]					*
Loan		[siːl]				*!	
/væt/	☞	[væt]					*
Loan		[fæt]				*!	

Note that though the constraints are reranked, only a single set of constraints is necessary for each set of synchronic derivations, and no stratum-specific Faith constraint is required. Also note that although the *Core-Periphery* model requires separate *ad hoc* constraints governing initial voiced fricatives due to the strict phonological requirements of the strata, in my model one constraint is able to account for all of the fricative voicing data.

This elegance and simplicity comes at the cost of specifying different underlying representations for the borrowed Latin lexical items, but each of these representations themselves follows naturally from the constraint rankings active at that time during the development of the language. So, not only is my model able to do all the work of the *Core-Periphery* rankings with fewer constraints, but I also capture the wider generalizations about the actual processes active in Old and Middle English to produce these forms that the *Core-Periphery* model misses (that the allowance of initial [v] and [z] is due to reranking of the same constraint as the allowance of [ð], for example).

To sum up my analysis, a massive constraint reranking occurred sometime after the Latin borrowings mentioned above, which created a large number of accidental gaps in the phonotactics of English. Since all words already in the language, including the borrowings from Latin, were put through the filter of this constraint ranking, by the time the constraints were reranked there were no longer any native words available to reveal these accidental gaps. Only through later borrowings and phonological changes, such as the loss of final /ə/ and voicing of initial unstressed /θ/, were these accidental gaps revealed. In the case of /ʒ/, for example, it was hundreds of years before sound change and borrowings revealed the accidental gap.

In the model I propose, we see that allowing underlying forms to reasonably account for alternations seen in the data streamlines the model and reduces the constraint processing load in addition to supporting learnability in acquisition. Updating underlying forms to reflect no-longer-productive alternations due to outdated constraint rankings leads to a much more natural and straightforward acquisition process for children. Now, instead of a child having to somehow discern the original foreign pronunciation of a thousand-year-old loanword, what they hear from their parents is what they get.

7 Determining the Synchronic Ranking of Constraints

If, as I have argued above, morphophonological alternation in lexical items is not necessarily the best way to determine the synchronic phonological constraint ranking of a language, then what is? In this section I argue that the only sure indicators of highly ranked constraints are adaptation mechanisms of novel sound sequences, which are most clearly demonstrated in recent loanwords.

7.1 Loanword Adaptations

It has long been recognized that loanword adaptation mechanisms reveal aspects of the borrowing language not discernible from the native lexicon alone (Hyman 1970, Wetzels 2009). I maintain, following Clements (2001) and Herd (2005), that loanword adaptation mechanisms are the result of the constraint rankings already present in the native phonology. However, I also believe that constant exposure to a novel sound sequence in a large number of loanwords from the same source can eventually trigger a reranking of the constraints of the borrowing language. As a result, when a language adopts loanwords that contain a novel sound sequence, I argue that the borrowing language will address the new sequence in one of three ways:

> **1)** The language modifies the sequence to fit its existing phonotactic constraints. The constraint ranking remains unchanged and continues to modify the sequence in future borrowings.
>
> **2)** The language adopts the new sequence immediately with no modification.
>
> **3)** The language initially modifies the sequence to conform to the current phonotactic constraints of the language, but over time loosens its phonotactic constraints to accept the new sequence without modification in later borrowings.

The first option is exemplified by Itô and Mester's SyllStruc constraints that limit codas to place-linked consonants and disallow complex onsets and codas. These highly ranked constraints have persisted with minimal changes since the earliest historical attestation of Japanese, and remain highly ranked today. This is seen in modern borrowings of English words with complex clusters such as *strike*, which becomes *sutoraiku* in Japanese. The fact that these epenthesis adaptation processes are currently active in modern borrowings into Japanese shows that these constraints are still highly ranked in modern Japanese phonology.

The second borrowing option is exemplified by Sino-Japanese words with word-internal clusters of a nasal followed by a voiceless stop segment. As Itô and Mester mention, in these ancient borrowings (such as *hantai* 'opposite' and *shinpai* 'worry'), NT clusters are adapted without modification, in spite of the No-NT constraint present in the older Yamato lexicon. Under my analysis, this ease of adaptation indicates that, at the time these items entered the Japanese lexicon, the No-NT constraint was already no longer highly ranked, allowing the Sino-Japanese words to be borrowed as-is. However, as mentioned above, all Yamato words had already neutralized any prior NT/ND distinctions due to the highly ranked No-NT constraint at an earlier stage of the language. Thus, the adoption of Sino-Japanese words without modification of NT sequences has the effect of revealing (and filling) this accidental gap in Japanese phonotactics created by the reranking of the No-NT constraint after it had neutralized all earlier postnasal voicing distinctions.

The final pattern is exemplified by borrowings from English with the sequence [ti] in the late

1800s and early 1900s, such as *chiketto* 'ticket' and *shiti* 'city'. In Itô and Mester's (1995) analysis, these assimilated loans should incur a violation of a NO-TI constraint that outranks FAITH, explaining the palatalization seen in *chiketto*. Newer, unassimilated loans would rank FAITH higher initially, then, as they become more assimilated, they would similarly become more constrained as they move closer to the core of the Japanese lexicon. According to Crawford (2009), however, citing data from Arakawa (1977), before 1890 the majority of borrowed words with [ti] surfaced in Japanese as [tʃi], and after 1930 the majority surfaced as [ti], "with a gradual shift from the TI→ČI to the TI→TI adaptation strategy taking place from 1870-1930" (Crawford 2009: 70–71). This indicates that, before 1890, NO-TI was a highly ranked constraint in Japanese phonology, resulting in the modification of loans with the sequence [ti]. Over time, however, as large numbers of loans with [ti] were borrowed into Japanese, speakers became more familiar with this sequence, and more and more speakers reranked NO-TI below FAITH, until by 1930 practically no speakers had trouble with this sequence[14]. It is worth pointing out that words initially borrowed with a [tʃi] pronunciation have retained this pronunciation throughout the history of their usage, while words first borrowed with [ti] have also retained [ti]. There has been no indication of these lexical items individually assimilating toward or away from the core of the lexicon. This data supports the conclusion that the [ti]/[tʃi] alternation is a lexically stored alternation, not one resulting from a phonological constraint still highly ranked in the modern Japanese language.

These three different adaptation mechanisms illustrate that lexical items closer to the "core" of the lexicon often leave accidental gaps in the synchronic phonotactics of a language, and that loanwords are useful for revealing these accidental gaps. Older loanword strata themselves may also leave accidental phonotactic gaps, however, if the phonological constraints have been reranked since their borrowing, as seen in §3 above. Thus, only recent loans that have likely not been superseded by a constraint reranking are a reliable indicator of a language's synchronic constraint set.

8 Conclusions

In this paper I have shown first and foremost that not all alternations present in a data set are the result of traditional interaction of phonological constraints. To attribute lexical alternations to the phonology can in fact be detrimental to developing an appropriately streamlined and constrained model as well as to capturing all relevant generalizations present in the data. Using data sets from both Japanese and English, I have shown that the stratal phenomena present in both languages, though analyzed as different in the past, are actually of the same type. I have argued in favor of updating the underlying forms of what were at one time predictable phonological alternations, once constraint reranking has removed these processes from productivity. This updating allows us to account for stratal data with fewer constraints while capturing more generalizations than the *Core-Periphery* model, which offers a descriptively nice synchronic account, but ultimately fails to motivate the different behavior of each stratum. Updating the underlying representations in this manner has the additional benefit of improving the learnability of the model in child acquisition.

In addition, we see that these supposedly non-productive alternations that should be confined to individual lexical items can still affect other lexical items through analogy. As such, we need a working model of analogy to complement our phonological models. My preliminary thoughts on this issue, containing a brief overview of various attempts to account for analogy, both within

[14]This process could possibly be partially due to an increase in English/Japanese bilingualism, reminiscent of Paradis & LaCharité (2008), who argue that increased bilingualism leads to increasing accuracy in loanword adaptation.

Optimality Theory itself, and also in neural network models in cognitive science, appear in the following Appendix.

Once the relationship between phonological and analogical processes are understood more fully, my account of lexical strata could give us more insight into the diachronic/synchronic relationship. The benefits of my analysis come at the cost of lexical updating to account for diachronic phonological change, a weakened morphemic principle, and the resulting decreased role of synchronic phonology, but offers a more accurate account of the data, and successfully marries synchronic systematicity of language with the reality of language change.

References

Anttila, Arto. 1997. Deriving variation from grammar. *Amsterdam Studies in the Theory and History of Linguistic Science Series 4*, 35–68.

Anttila, Arto, & Cho, Young-mee Yu. 1998. Variation and change in Optimality Theory. *Lingua*, **104**(1), 31–56.

Arakawa, Soobee. 1977. *Kadokawa gairaigo jiten [Kadokawa loanword dictionary]*. Tokyo: Kadogawa Shoten.

Benua, Laura. 1997. *Transderivational identity*. Dissertation. University of Massachusetts Amherst.

Bermúdez-Otero, Ricardo. 2006. Phonological change in optimality theory. *Encyclopedia of language and linguistics*, **9**, 497–505.

Clements, George N. 2001. Representational economy in constraint-based phonology. *Distinctive feature theory*, 71–146.

Clements, George N. 2003. Feature economy in sound systems. *Phonology*, **20**(03), 287–333.

Crawford, Clifford James. 2009. *Adaptation and transmission in Japanese loanword phonology*. Ph.D. thesis, Cornell University.

Dobson, Eric John. 1957. *English Pronunciation, 1500-1700: Phonology*. Vol. 2. Clarendon Press.

Dupoux, Emmanuel, Kakehi, Kazuhiko, Hirose, Yuki, Pallier, Christophe, & Mehler, Jacques. 1999. Epenthetic vowels in Japanese: A perceptual illusion? *Journal of experimental psychology: human perception and performance*, **25**(6), 1568.

Frellesvig, Bjarke. 2010. *A history of the Japanese language*. Cambridge University Press.

Harbert, Wayne. Personal Correspondence, April 30, 2015.

Hearn, Ryan, Long, Yanyu, Moroney, Mary, & Little, Carol Rose. 2015. *Voice Alternations in English Plurals*. Presentation at Cornell University, March 2015.

Herd, Jonathon. 2005. Loanword adaptation and the evaluation of similarity. *Toronto Working Papers in Linguistics*, **24**.

Hyman, Larry. 1970. The role of borrowing in the justification of phonological grammars. *Studies in African linguistics*, **1**(1), 1.

Itô, Junko, & Mester, Armin. 1993. Japanese phonology: constraint domains and structure preservation. *A handbook of phonological theory. Blackwell Handbooks in Linguistics Series.(to appear)*.

Itô, Junko, & Mester, Armin. 1995. The core-periphery structure of the lexicon and constraints on reranking. *Papers in optimality theory*, **18**, 181–209.

Itô, Junko, & Mester, Armin. 2004. The Phonological Lexicon. *Pages 552–564 of:* McCarthy, John J (ed), *Optimality Theory in Phonology: A Reader*. Wiley-Blackwell.

Jacobs, Haike. 1995. Optimality Theory and sound change. ROA-129-0496.

Kenstowicz, Michael. 2005. Paradigmatic uniformity and contrast. *Pages 145–169 of:* Downing, L., Hall, T. A., & Raffelsiefen, R. (eds), *Paradigms in Phonology.* Oxford University Press, Oxford.

Kiparsky, Paul. 1973. *Three dimensions of linguistic theory.* TEC.

Kiparsky, Paul. 2008. Fenno-Swedish quantity: contrast in Stratal OT. *Rules, Constraints, and Phonological Phenomena Oxford: OUP.*

Kiparsky, Paul. 2012. Grammaticalization as optimization. *Grammatical change: Origins, nature, outcomes*, 15–51.

Lahiri, Aditi, & Dresher, B Elan. 1999. Open syllable lengthening in West Germanic. *Language*, 678–719.

Lass, Roger. 1999. Phonology and morphology. *The Cambridge history of the English language*, **3**, 1476–1776.

Lovins, Julie Beth. 1975. *Loanwords and the phonological structure of Japanese.* Indiana University Linguistics Club.

McCarthy, John J. 1999. Sympathy and phonological opacity. *Phonology*, **16**(03), 331–399.

Minkova, Donka. 1982. The environment for open syllable lengthening in Middle English. *Folia Linguistica Historica*, **16**(Historica vol. 3, 1), 29–58.

Minkova, Donka. 2014. *A historical phonology of English.* Edinburgh University Press.

Myers, James. 2002. Exemplar-driven analogy in Optimality Theory. *Pages 265–300 of:* Skousen, R., Lonsdale, D., & Parkinson, D. (eds), *Analogical Modeling: An exemplar-based approach to language.*

Paradis, Carole, & LaCharité, Darlene. 2008. Apparent phonetic approximation: English loanwords in old Quebec French. *JOURNAL OF LINGUISTICS-CAMBRIDGE-*, **44**(1), 87.

Pinker, Steven. 1999. *Words and rules: The ingredients of language.* Basic Books.

Pinker, Steven, & Prince, Alan. 1988. On language and connectionism: Analysis of a parallel distributed processing model of language acquisition. *Cognition*, **28**(1), 73–193.

Pinker, Steven, & Prince, Alan. 1994. Regular and irregular morphology and the psychological status of rules of grammar. *The reality of linguistic rules*, **321**, 51.

Rice, Keren. 1997. Japanese NC clusters and the redundancy of postnasal voicing. *Linguistic Inquiry*, **28**(3), 541–551.

Rumelhart, David E., McClelland, James L., Group, PDP Research, *et al.* 1988. *Parallel distributed processing.* Vol. 1. IEEE.

Shibatani, Masayoshi. 1990. *The languages of Japan.* Cambridge University Press.

Skousen, Royal, Lonsdale, Deryle, & Parkinson, Dilworth B. 2002. *Analogical modeling: An exemplar-based approach to language.* Vol. 10. John Benjamins Publishing.

Smolensky, Paul. 1995. On the internal structure of the constraint component Con of UG. Paper presented at UCLA.

Sturtevant, Edgar H. 1947. An introduction to linguistic science.

Wetzels, W Leo. 2009. Nasal harmony and the representation of nasality in Maxacalí. *Loan phonology*, **307**, 241.

Appendix: Productivity and Analogy

Throughout this paper, I have argued that the *Core-Periphery* model attempts to account for alternations that are no longer productively part of the phonology of a given language, and that these alternations are better accounted for by the lexicon. If these alternations are no longer actively part of the phonology, however, the immediate question is why then do we see tokens of these supposedly lexicalized alternations showing up in wug tests of nonce forms and spreading to other lexical items that would otherwise show regular, "productive" alternations?

For example, in Hearn *et al.* (2015), we asked twelve native English speakers to produce twenty-two plural forms from nonce forms given in a variety of phonotactic environments with final [f]. All but three of the participants produced at least one novel plural form with final [vz], and eight of the twelve speakers produced at least six plural forms with the voiced variants. Clearly these alternations are productive at some level. We even see this alternation intruding on true English lexical items like "roof", whose plural often surfaces as "rooves" instead of the standard "roofs". If words containing these alternations are supposedly lexicalized, why do they still appear to be productive?

To merely call these forms "analogical" with no explanation would be passing the buck, especially when the source forms for the analogy are the direct result of the Old English medial voicing process described above. Since my model specifically asserts phonological nonproductivity of these alternations, to leave the questions raised by analogy unaddressed would be unsatisfying. Consequently, in this appendix I give an overview of possible treatments of analogical forms to provide further evidence that these alternations are due to intralexical influence, not *phonological* constraint interaction.

OT-Internal Explanations: Output-Output and Paradigmatic Uniformity Constraints

There have been multiple attempts within Optimality Theory to account for analogical effects, from McCarthy's Symapthy (1999) and Benua's Output/Output constraints (1997) to Paradigmatic Uniformity constraints (Kenstowicz 2005), each of which has their share of proponents, benefits, and difficulties. What these approaches all have in common, however, is that they can only account for analogy within the paradigm of a single lexical item, and not of the sort necessary to show how forms like *hooves* can influence completely different lexical items like *roofs*/*rooves*.

The basic idea of Output/Output (O/O) constraints is that lexical base forms exert a faithfulness influence over their derivatives, i.e. the Output of the base form partially determines the Output of the derived form. This can be useful for our purposes when we see levelling within a single paradigm, illustrated below with selected forms from the paradigm of *fish*. Recall that /sk/ becomes /ʃː/ only finally and before front vowels, not back vowels. Thus in the original Old English paradigm on the left below, there would have been an alternation between [ʃː] in the genitive singular and [sk] in the nominative plural. In later Old English, however, [ʃː] would have become generalized throughout the paradigm due to the influence of the Output form of its base, [fiʃ].

(21)

	Original Paradigm	*Levelled Paradigm*
Nom. Sing.	[fiʃ]	[fiʃ]
Gen. Sing.	[fiʃːes]	[fiʃːes]
Nom. Pl.	[fiskas]	[fiʃːas]

O/O constraints account for this development quite nicely. With a highly-ranked constraint HeadMax-ba, which ensures that every segment in the head output is represented in the output of the derived form, we can correctly generate the later pronunciation [fiʃːas].

(22) Input /fisk+as/, Base [fiʃ]

	HeadMax-ba	Faith
[fiskas]	*!	
☞ [fiʃːas]		*

As useful as O/O constraints may be within a single lexical paradigm however, they still can't help us solve our main problem, namely, influence between separate lexical items. Paradigm Uniformity (PU) constraints are more powerful and less theoretically constrained than O/O constraints, in that all members of a single paradigm influence the generation of other paradigm members, making them useful for dealing with paradigm levelling of the type seen above in (21) as well. However, like O/O constraints, PU constraints are meant to account for analogy within a single paradigm, and not between separate lexical items, leaving us yet again without an OT-internal account for the analogical productivity of phonologically nonproductive alternations.

All is not lost: the takeaway from this section should not be that Optimality Theory has no good model within which to represent interlexical analogy, but rather that OT does have mechanisms by which to represent analogy generally, and that the potential exists within the theory to eventually account for interlexical analogy as well. See Section 5.3 below for one such attempt.

OT-External Explanations: Connectionist and Analogical Models

In reaction to what some saw as an inability of rule-based frameworks to account for language data in the 1980s, research into neural networks saw rapid expansion, especially in areas dealing with analogical relationships between lexical items and morphological forms. This research developed to the point that models completely separate from phonology as we know it, built entirely from analogical relationships within the neural network, began to generate surface representations solely through the interactions of these interconnected stored lexical forms. Two types of these models, connectionist models (cf. Rumelhart *et al.* 1988) and the Analogical model (Skousen *et al.* 2002), are most often discussed in the literature, with the main difference between them being whether they are prototype-based (connectionist) or instance/exemplar-based (analogical). They bring similar approaches to the table, so for space reasons only the connectionist model will be described below for its relevance to the current discussion.

The connectionist model is an interesting storage association model first used to account for English regular and irregular past tenses. It is notable for the similarity of the results of its learning and extension algorithms to that of errors produced by children during development. The model memorizes new past tense forms as it learns them, generalizes these patterns by phonological similarity, and then extends these generalizations to generate new past tense forms. As the model memorizes more forms, its predictions become more and more accurate, and the decisions and mistakes it

makes along the way closely parallel those made by children during development: it overgeneralizes weak verb forms (*catched* for *caught*), correctly analogizes other strong verbs like *clung*, produces blend forms like *gaved*, and even overgeneralizes weak past tense forms to strong forms that earlier in its development it had produced correctly, just as children do (for example, *gived* for earlier *gave*).

It accomplishes these feats by dividing words into three-segment pieces called Wickelphones and relating these pieces to other identical pieces throughout the language. It uses these relationships to generate new forms based on statistically probable combinations of Wickelphones. For example, *creep* would be divided into pieces like [*cr*, *cre*, *ree*, *eep*, and *ep*]. These forms would be compared to other Wicklephones generated from words like *keep*, *sleep*, and *step* and their past tense forms to ultimately generate the correct form *crept*. One strength of the model, however, which is important for our discussion, is that these decisions by the model are not all or nothing, but are statistical probabilities. So, even though *crept* is the more likely output form, the model also predicts that other forms, such as *creeped*, will be produced by speakers from time to time. This is exactly what we see in native speech, and is strikingly reminiscent of the types of plural analogical relationships mentioned above that we were hoping to find an account for. "Incorrect" forms like these are not only accounted for by connectionist models, but actively *predicted* by them.

These models are not without their shortcomings, of course. Pinker & Prince (1988) provide a scathing critique of the connectionist model, pointing out that Rumelhart and McClelland's pattern association model can only *produce* past tense forms, and cannot *recognize* them as all speakers of English are able to do. Also, due to the segment-based nature of the model, it is not able to deal with homophones (*break/broke* vs. *brake/braked*, for example) or the results of morphological compounding (*maple leaves* vs. *The Maple Leafs*). Further, they point out some of the more ridiculous of the incorrect past tense items generated by the model, such as *mail/membled*, *brown/brawned*, *smoke/smokeded*, and claim that the model overgenerates, producing alternations that do not occur in any human language. Finally, Pinker and Prince question the similarity between child acquisition and the pattern association model, stating:

> "The child who *has not yet figured out* the distinction between regular, subregular, and idiosyncratic cases will display behavior that is similar to a system that is *incapable of making* the distinction – the RM Model." (136)

Mixed Models

Recognizing the valuable insights made by both traditional phonological models (rule-based and constraint-based) and neural network models, some researchers have attempted to combine them in various ways to capitalize on their individual strengths and overcome their inherent weaknesses.

One such attempt is that of Exemplar-Driven OT (Myers 2002), intended to account for interlexical analogy by incorporating elements of Skousen's Analogical Modeling into Output/Output constraints within Optimality Theory mentioned above in Section 5.1. To account for the "four-part" nature of interlexical analogy, Myers implements the notion of constraint conjunction (cf. Smolensky 1995), by which multiple constraints can be joined by Boolean operators into a single complex constraint requiring parallels between all four pieces of the analogy; i.e., for a table generating the past tense of *dive*, a complex constraint OO∧OO-(*drive*,*dive*;[ayv])(*drive*$_{PAST}$,*dive*$_{PAST}$;[o]) requires that the vowel present in the past tense of *dive* correspond to the vowel in the past tense of *drive*. These complex constraints can be ranked relative to constraints generating regular verb forms to produce dialectal variation between *dived* and *dove*. By creating and ordering multiple

complex constraints with different possible comparanda exhibiting different inflectional patterns, a statistical model approaching Skousen's Analogical Modeling system can be implemented. A similar analysis could be proposed to account for the dialectal variation between initial and final [ʒ] and [ʤ] in *genre* and *garage*, due to the paucity of analogical forms exerting positive pressure to produce [ʒ]. Though Myers himself states that his model is not yet fully compatible with the Analogical model, and gives less accurate results, the Exemplar-Driven OT model remains an interesting exercise in combining OT and neurological modeling.

The most famous of these attempts to combine phonological and neural models is likely the dual-model approach of Pinker & Prince (1994), in which regular, productive phonological alternations are produced by phonological rules, and irregular inflectional patterns have separate entries in the lexicon for each form. However, these separate entries are associative, with the relationships between them acting as predicted by the connectionist model in that they can assert productive influences over other lexical items based on similarity of phonological form, whether or not they regularly show the same type of inflection.

By assigning productive and nonproductive alternations to two different systems, Prince and Pinker predict that these processes will act separately, but with overlapping effects. This is described in Pinker (1999) as follows:

> "[I]rregular inflection depends on *memorized* words or forms *similar* to them, but regular inflection can apply to *any* word, regardless of whether the word is readily retrievable from memory. Regular inflection has that power because it is computed by a mental operation that does not *need* access to the contents of memory." (119)

This appendix has attempted to provide a brief survey of possible approaches to modeling analogy. Though this research is still in its youth, it seems clear that there are promising alternatives to the traditional approach of accounting for all systematic alternations present in a language through either rule-based or constraint-based phonological models alone. Hopefully in time a model of this nature can not only account for, but also predict, analogical change in human language. This would give us the freedom to streamline the phonology proper, in order to account for synchronically productive alternations alone.