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Intrinsic vs. Extrinsic Ordering, Rules, and Exceptions

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Morris and I were invited separately as speakers at this symposium, and had originally planned to deliver separate lectures. However, we quickly realized that, having both thought about these phenomena and their implications for "Critical Challenges and Future Prospects", we would pursue research together, which we report upon today.

We agreed on the following four principles:

(A) Phonological computation consists of the application of structural changes to representations that satisfy a structural description

(B) The application of each structural change results in a new level of representation

(C) The sequence of application of structural changes is partly determined by an extrinsic ordering, one that is informationally encapsulated from the structural descriptions.

(D) When certain structural changes do not apply, even when expected by the general principles in (A)-(C) above, they constitute *exceptions*. In fact, we explore here a bolder claim: that there are two components: rules which have listed exceptions and are modeled by diacritics on the underlying representation of lexical items, and rules which apply *only* to listed items, and that these two constitute separate modes of computation.

The latter two principles have not received a tremendous amount of attention since the 1970s. Starting with (C), for example, Greg Iverson's chapter on Rule Ordering in the Handbook of Phonology documents the fervent research into the interactions of rules and the subsequent disappearance of the question: "In the 1970s, considerations such as these led to the hypothesis of *universally determined rule application*, i.e., the idea that the ordering relation between rules (and rule applications) is predictable from other aspects of the grammar, and from principles with the universal force of the "Elsewhere Condition" (Kiparsky 1973), "Proper Inclusion Precedence" (Sanders 1974), or the "Survival Constraint" (Anderson 1974). By the end of the decade, however, attention had turned more toward the increasing richness of phonological representation than to the specifics of rules and their interaction" (p.611-612).

The second question was addressed most attentively in Wim Zonneveld's 1978 dissertation and book, "A Formal Theory of Exceptions in Generative Phonology". Again, Iverson's historical assessment perhaps holds here as well: the increased emphasis on the formalisms of autosegmental phonology and feature geometry led to less attention being paid to the problem of formal identification of representations that manage to elude otherwise regular rule application.

The two examples that we study in this paper address the two questions of rule ordering and exceptions. In the first example, we show that the inter-vocalic obstruent clusters [ks] and [gj] as in the English verbs accede and suggest are lawful consequences of the fact, on the one hand, that English is subject to Velar Softening (electric - electricity) and, on the other hand, that in words such as recede and recite the intervocalic /s/ is not voiced, whereas it is voiced in resume and resort. Our second example provides an account of the superficially highly irregular allomorphs of the PlGen of modern Czech, by showing that these result from the fact that one of the central processes of Slavic phonology - Jakobson's rule of vowel deletion - does not apply in the PlG of some nouns.

The property that is shared by these two examples is that in both of them individual words must be treated as exceptions to a particular rule of the phonology. Our examples thus constitute a challenge to the famous Neogrammarian dictum that all sound laws are exceptionless. In fact, our examples show that there are two different kinds of exceptionality: on the one hand, a particular word may be an exception to a specific phonological rule, and on the other hand, there are rules that apply only to a specific list of formatives.

The latter set of rules, i.e. rules that apply only to listed items were introduced into phonology in Chomsky and Halle 1968 (SPE), where they were called "readjustment rules" (cf. SPE, p. 10.). Readjustment rules are now considered part of the morphology, i.e., part of the component of a grammar that is responsible for assigning phonological exponents to abstract morphemes such as "Past" or "PlGen" or "Superlative" (see Halle 1997). Readjustment rules, however, do not constitute part of the direct realization of morphosyntactic features. All readjustment rules take effect before the rules of the phonology proper. This has important consequences for the solution of particular problems, as will be demonstrated below, especially in the discussion of length alternations in the noun stems in the Czech declension. Since readjustment rules apply only in listed environments, they have no listed exceptions. They contrast in this respect with ordinary phonological rules, which, as will be shown, commonly include a list of exceptions to which the rule

does not apply.

As is well known, Velar Softening does not apply across the board. In every such semiproductive process, there is a tension between Rules and Words, Algorithms and Data Structures, Operations and Representations. As we know that Velar Softening occurs in "electricity" but not "king" or "mawkish", are the latter two to be taken as exceptions? Or is Velar Softening to be relegated to the domain of memorization of surface alternations?

Although Jean Berko had pioneered Wug testing already in 1958, her methodology has not enjoyed a resurgence until the last 10 years or so, during which an increased emphasis has been placed on experimental techniques in phonology. Janet Pierrehumbert has recently published a paper entitled "An Unnatural Process", which illustrates that speakers reliably extend Velar Softening to novel forms. If speakers are indeed applying the rule of Velar Softening to words they have never heard before, then the thesis of memorized alternations clearly cannot be maintained. We return to the point in detail below.

In the second half of the paper, we examine the Czech nominal declension, where the marking of rule-exception in a systematic subpart of the lexicon leads to consequences and interactions with a number of other independent processes. Anticipating the results, it turns out that the fact that a set of stems are marked as exceptions to an otherwise well-motivated rule of vowel deletion renders them eligible for a number of subsequent rules, otherwise inapplicable.

Both English and Czech involve a sequence of rule applications, which at various points require extrinsic ordering, while at others, disjunctive application of the rules follows from formal principles.

Although there is nothing logically problematic with rule-ordering, and as Chomsky (1967) discusses at length, nothing inherently "simpler" about a system without extrinsic ordering. In fact, the property of grammars that they may contain a totally ordered list transcends the architectural question of rules vs. constraints. Every OT grammar contains an ordered ranking of constraints, and this ranking is completely independent of the content of the constraints themselves.

However, an active consideration that does legislate against excessive use of extrinsic ordering in any grammar is connected with its acquisition. In particular, it is an open question whether the transitivity property of a set of pairwise-ordered rules or constraints is actively learned.

In a recent study, Guest, Dell, and Cole (1999) found that learners of an artificial OT grammar could not even, after many hours of rehearsal, exposure, and production, make the transitivity conclusion. Given evidence that A is ordered before B, and that B is ordered before C, their subjects' grammars did not reliably contain the deduced ordering that A is ordered before C.

Many crucial constraint rankings, after all, are only pairwise, and as such, are perhaps better modeled as binary parameters. Consider for example the 12 syllable types of languages in the world documented by Blevins (1995). They can be modeled by four parameters: Obligatory-Onset, No-Coda, Complex-Onset, and Complex-Coda. Of the 16 language-types predicted by the four parameters, four are ruled out by a dependent-parameter relationship (as outlined in Lightfoot 199x), for no language would have a positive value for Complex-Coda and a positive value for No-Coda. Hence, modeling the inventory of syllable structures with parameters allows fairly independent setting of each and a well-constrained search space for the learner.

In an OT model, however, there would be these four constraints, plus a faithfulness constraint, and hence 120 possible languages, with no obvious mechanism for ruling out certain combinations, as the architecture contains no notion of inter-constraint-dependence. This is a consequence of imposing total ordering on a set of constraints and allowing all possible total ordering.

Clearly, then, the amount of arbitrariness in the system, in this case, the freedom of relative ordering of rules without reference to their structural descriptions, leads to a more unconstrained task for the learner. Our discussion, then, will be guided by considerations of seeing where extrinsic ordering can be done without, and where it is unavoidable.

With these preliminary remarks, we turn to the empirical data.

1. The phonology of prefix+stem verbs in English

A topic of central concern to phonology has always been the treatment of alternations; i.e., the fact that a given morpheme appears in different phonetic guises in different contexts and that the relation between the different guises (sometimes called allomorphs) is governed by readily stated principles. A typical example of such alternations is illustrated in (1), where affixation is accompanied by changes in the stem final vowel.

- (1) divine - divin-ity serene - seren-ity sane - san-ity
Semite - Semit-ic athlete - athlet-ic volcan-o - volcan-ic

Alternations like those in (1) are found in all languages that have ever been studied, and the evolution of the theory of phonology has been profoundly influenced by attempts to deal with these and similar examples. We return to these examples below.

A second alternation of interest here is that found in the English prefix-stem verbs illustrated in (2).

(2)

consist	consult	consign	contain	congest	concede	conceive
persist	--	--	pertain	--	--	perceive
resist	result	resign	retain	--	recede	receive
insist	insult	--	--	ingest	--	--

As shown by the examples in the first three columns of (2) stems beginning with /s/ change it to /z/ when the prefix ends in a vowel. In SPE, where this problem was first discussed, the alternations were accounted for by the voicing rule (3).

(3)
 Structural Description: V s V
 Structural Change: s >> [+voice]

As illustrated in (4), there are numerous intervocalic contexts where (3) does not apply. We assume that each word in (4) is marked as an exception to rule (3).

(4) parasite chromosome asylum philosophy

As shown by the examples in the last two columns of (2), rule (3) does not apply everywhere even in the verbs under study here. Unlike the examples in (4) those in the three right-hand columns of (2) are not lexical exceptions to rule (3), but are rather lawful consequences of the phonology of the language.

English is subject to the alternation between dorsal and coronal consonants illustrated in (5)

(5) medic-ate plac-ate electric critic
 medic-ine placid electric-ity critic-ize

Damasc-us innoc-u-ous
 Damasc-ene innoc-ent

analog ideolog pedagogue reg-al rig-or
 analog-ize ideolog-y pedagog-ic reg-ent rig-id

The SPE way of dealing with these examples was to posit rule (6) that changes /k/ >> /s/ and /g/ >> /j/ before certain vowels. (In

SPE this rule was called Velar Softening.)¹

(6)

Structural Description:

[dA:Dorsal, -sonorant] [dA:Coronal, -low]

Structural Change: dA becomes Coronal

(changes /k/ >> s and /g/ >> j)*

In Halle (2004), dorsal-coronal alternations of this sort were shown to exist in not only English and Romance, but also in unrelated languages such as Kiowa and Maimande.

Like /s/ Voicing (2), Velar Softening (6) also has lexical exceptions, as shown in (7).

(7) kind kin keen keg tak-ing tack-y anarch-y
guise give geese get clogg-ing fogg-y

Before discussing the exceptions we note that rule (6) provides a straightforward account for the absence of voicing in the last two columns of (2). All we need to do is to posit that the stems /-cede/ and /-ceive/ actually begin with /k/ and that this /k/ turns into /s/ before the front vowel /iy/, but that this change takes place after the voicing rule (3) has had a chance to apply. Specifically, the claim is that the surface representation is derived not in one fell swoop, but in several steps as shown below

		s->z		k->s
(8)	re[s]ign	>>>	re[z]ign	>>> doesn't apply
	re[k]ede	>>>	doesn't apply	>>> re[s]ede

Thus, the view of Velar Softening as an active phonological rule, combined with its ordering with respect to intervocalic /s/-voicing, yield a systematic, rather than accidental account for the fact that the obstruent in *receive* is not voiced. Rather than directly pursuing an account in terms of exceptions (i.e., by saying that all stems such as -ceive are exceptions to intervocalic voicing), we can appeal instead to the interaction of /s/-voicing with an independent rule of the phonology.

It is instructive to consider the alternatives, however, to extrinsically ordering Velar Softening after Intervocalic Voicing. First of all, no single constraint ranking can handle the problem, and even a multistratal one will have to extrinsically order the constraints within and across strata.

¹For details of the formal mechanism involved in Velar Softening, see Halle 2004 (LSA talk).

This effectively eliminates an alternative OT account that would not be a notational variant.

The next possibility is an appeal to the Elsewhere principle. However, there is no subset relation between the inputs that satisfy the structural description for the two rules. On the right-hand side of the rule, both occur before vowels. However, the set of vowels that trigger Velar Softening is more restricted than the set that trigger /s/-voicing, which would predict VS to feed /s/-voicing, contrary to fact. Hence, intrinsic ordering based on rule specificity cannot be appealed to in an account for the ordering of the application of these two rules.

The left-hand side of the rule is, at present, formulated with no restrictions. The attentive listener may find this to be overly liberal. It is at this point that we turn to the experiment conducted by Janet Pierrehumbert, and subsequent experiments piloted by Donca Steriade, reported in her comments on Pierrehumbert's paper at LabPhon 8.

Pierrehumbert's subjects were presented, auditorally but not visually, sentences providing context for the formation of a noun from an adjective. Subjects were told to make a noun in any way they wished. Examples were of the form:

(8a)

Before Pierre stood an electrifyingly hovac sculpture. In his entire career as a curator, he had never before seen such a perfect example of (BLANK).

The experiment was controlled, counterbalanced, and randomized. There were three relevant types of stimuli. The first were words with canonically Latinate form, as determined by consonant clusters, prefixes, and a trochee-final foot, such as *interponic* and *criotic*. For these *-ic*-final targets, of the responses in which subjects created nouns using *-ity* (rather than *-ness*), 93% applied Velar Softening. The result demonstrates that VS is not limited to existing word-pairs, as subjects had never heard either *criotic* or *crioticity* before. Skeptics could, of course, appeal to analogy with all *-ic* final stems. However, the presence of Velar Softening in *cede*, *ferocity*, *pharmacist*, and a number of other examples essentially falsifies this hypothesis in its simplest form.

Of more interest, then, is the second group of stimuli in Pierrehumbert's experiment: bisyllabic words with a primary stress-secondary stress contour, and a [-high] vowel in the final syllable, such as *hovac* and *trylec*. Of these forms, when subjects were asked to suffix *-ity*, 83% applied Velar Softening.

Having concluded that the scope of Velar Softening does not mention in its context the identity of the preceding vowel, nor the prosodic shape of the stem, Donca Steriade went on to see if the generalization was even broader. Steriade reports that although Velar Softening never applies to a monosyllabic base (citing *Chekism* and *yogist* as extant examples), the very identity of the segment preceding the velar does not matter. Thus, her subjects applied VS even in postconsonantal contexts, yielding [tribelk]-[tribelsity]. Thus, there is no immediate left-hand context at all in the structural description of VS.

Finally, Steriade reports that diacritics such as [+Linate] do not seem to play a role in the context for VS. She created words with very Germanic initial clusters, such as *dw*, *tw*, *gw*, *sm*, *sn*, *thw*, and *thr*, and found that Velar Softening still applied: for the input *dwalek*, "only *dwalesity* is possible" (p. 3).

Both Steriade and Pierrehumbert conclude that "speakers go considerably beyond the evidence provided by known alternations" (p.3) and that "the k-s alternation is psychologically real" (p.9), respectively. Pierrehumbert calculates that in the entire English lexicon, only 25% of words ending in [Iti] end in [sIti], and only 9% of words ending in [Izm] end in [sIzm]. Before both endings, the phoneme /l/ is more common than /s/. Simple frequency tracking on the output, then, would predict Velar "Liquidization", which never occurred for any of the subjects. In addition, Pierrehumbert reports on a backformation task, in which subjects were asked to practice affix-stripping, creating *virgin* from *virginity* and *bright* from *brightness*. Although only 13% of subjects created *hovak* from *hovacity*, Pierrehumbert concludes that this is sufficient evidence to demonstrate that "faithfulness is not relevant in all situations, only those in which it may resolve uncertainty" (p.13).

These studies, then, provide confirming evidence that Velar Softening is a regular rule of the phonology, with exceptions, rather than a list of related word-pairs. And once Velar Softening is given status as a stage in the phonological computation, it clearly needs to be situated with respect to other phonological processes. We thus return to the issue of ordering.

An interesting hypothesis on rule ordering was advanced by Koutsoudas, Noll, and Sanders (1974): that there isn't any. They attempted to show that many cases of rule ordering could be instead reduced to essentially four different scenarios:

- 1) Elsewhere-type ordering, with rule-precedence determined by principles of Inclusion in Structural Description

2) *Simultaneous application*, which for example, eschews modeling Low German final consonant alternations as a derivation from *tag* to *tay* to *tax*, with spirantization of voiced consonants preceding devoicing, but rather applies the two rules simultaneously to *tag*.

(9) Ordered Application:

tag
tay (by Spirantization of Voiced Obstruents)
tax (by Devoicing)

Simultaneous Application:

tag
tax
(by Simultaneous Application of Spirantization and Devoicing)

This sort of schema is, in general, possible when two rules have structural descriptions that can be met simultaneously. This is not the case for /s/-voicing and Velar Softening in *re+kede*.

3) For cases of counterfeeding precisely like VS and s-voicing, Koutsoudas et. al advocate reanalysis/denial (as witnessed by a footnote in Koutsoudas' book that, given Kiparsky's neutralization condition, Velar Softening "is not a possible rule of English").

4) Persistent-Rules, to which we return, can apply anywhere in the derivation where their structural description is met (revived by Myers 1991). It is clear that this will not block the application of /s/-voicing after Velar Softening.

Hence, none of these solutions can supplant extrinsic ordering. There is however, a further possibility. In research on syntactic derivations, extrinsic ordering of transformations was to a large extent replaced by means of traces, a new component of the theory that allowed phrase-markers to maintain a history of the derivation. Traces are an enrichment of the representation that block the application of otherwise applicable rules.

(9a) **Who do you wanna help you.*

Ordering: Wanna-Contraction precedes wh- movement

(9b) *Who do you want t to help you*

No Ordering; Wanna-Contraction across a trace illicit.

One way to rule out **Who do you wanna help you* is to extrinsically order wanna-contraction before wh- movement, so that it is impossible to extract *who* and then subsequently contract *want* and infinitival *to*. Another option, however, is to simply restrict the theory of wanna-contraction, so that it

cannot apply to objects that contain a trace of wh- movement. The trace of wh- movement is a way of encoding a derivation that has already taken place within the representation itself, without necessarily allowing each rule reference to a global order. Syntactic rules became, in a sense, "persistent rules", applying whenever their structural descriptions, now suitably restricted, were met.

Returning to the example at hand, suppose that changes to the featural composition of segments leave "traces"; in particular, that the autosegmental delinking of Velar leaves a trace (or, dotted line for the visually-oriented). Suppose further that /s/-voicing cannot apply to any segment with a "trace" of featural-delinking. Then, the explanation for the lack of *rezede is not because Velar-Softening has applied "too late", and /s/-voicing can no longer apply. Rather, /s/-voicing could be a "persistent rule" that simply cannot apply to the representation resulting from VS.

A modicum of support for this proposal comes from the alternation in *sate-satiable*. As noted by Chomsky (1964), a spirantization rule converts /t/ to /s/ before the glide /y/², and a palatalization rule converts /sy/ to /j/ before a vowel:

(10)

Spirantization: t >> s in env. -- y
Palatalization: sy >> j in env. -- V

(It is clear that Palatalization can apply to the output of /s/-voicing, as witnessed by forms such as *vision*, in which a voiced strident-high vowel sequence become a voiced [-anterior] segment. This will not affect the following argument.)

The question is what blocks the application of /s/-voicing in the following derivation:

(11)

sejt+yable
sejs+yable (by Spirantization)
sejz+iable (by /s/-voicing)
sejdzable (by Palatalization)

Of course, an appeal to ordering may be made again so that /s/-voicing is ordered before Spirantization (as in SPE p. 229: "The Spirantization rule must follow the rule of s-voicing, since the [s] formed by rule [Spirantization] does not voice."). But since

²That spirantization is triggered by the glide /y/ and not by the vowel /i/ can be evidenced by contrasts such as *Gilbertian* vs. *Egyptian*.

there is no relative ordering of Spirantization and Velar Softening, we now require two pairwise ordering statements. Restricting /s/-voicing to "traceless" segments, on the other hand, requires a single statement only.

As a side note, English orthography reflects this restriction to a certain extent, as only segments that are isomorphically represented as "s" in orthography and pronounced [s] may undergo /s/-voicing, while non-isomorphic graphemes such as "t" and "c" never do.

The theory of enriching the representations of segments as a treatment of counter-feeding interactions is admittedly an extensive development of the theory. Inspection of more cases will verify its generality.

Although this accounts for the data presented so far, this is not the entire story. We still have no account for the data in (12a), where unexpectedly /s/ does not voice intervocalically, although the same stems undergo voicing in other environments as shown in (12b).

- (12) a. as-sist as-sign as-sume as-semble
as-similate as-sert as-sault
- b. re-sist re-sign re-sume resemble

Following SPE we assume that the examples in (12a) were subject to a rule that the prefix /a-/ triggers reduplication of the initial consonant of the verb stem. As shown in (13), if the rule of reduplication is ordered before rule (3) of /s/- Voicing, the correct outputs are generated. This rule of course exhibits an ordering statement: reduplication is linearized in this case before a cyclic rule³.

³In Fitzpatrick & Nevins (2002), it was argued that the actual linearization of reduplication must occur before Velar-Softening. Velar-Softening, however, is a Cyclic-rule, applying only to so-called "Level 1" affixes, as we have seen. Therefore, the hypothesis espoused by Mester (1986) that Linearization of reduplication occurs after all Cyclic rules and before all Post-Cyclic rules cannot be correct in its simplest form.

We illustrate the derivation of some sample forms below:

(13)		a+sist	re+sist	re+kiyd	a-kiyd
Reduplication		a+ssist	N/A	N/A	a-kkiyd
/s/ >>> /z/ in env. V + ___V		N/A	re+zist	N/A	N/A
Velar Softening (6)		N/A	N/A	re+siyd	a-ksiyd

As shown in the last column of (13), the account just presented makes an interesting prediction about the prefix /a/ and a stem of the form /kiyd/; it predicts that this form will surface with the consonant cluster [ks].

Two properties of the data reviewed above present serious difficulties for OT: they are opacity, on the one hand, and the fact that rules have lexical exceptions. The difficulties of principle that opacity presents to all types of OT solution have been noted by John McCarthy in his paper on sympathy. McCarthy's suggestion to complicate OT by invoking 'sympathy' is on our view an unwarranted complication of the theory just in order to deal with facts which the theory was not designed to handle. It resembles greatly the postulation of epicycles by astronomers opposing Copernicus.

The second problem is the fact -- also illustrated by the data presented here -- that individual lexical items may be marked to undergo or not to undergo a given rule. Thus obesity is an exception to the rule shortening vowels before -ity, and as a result the stem final vowel remains long, and like all other long vowels undergoes Diphthongization and Vowel Shift. Thus, the marking of an item as an exception to a rule only affects one step of the computation. The facts of Velar Softening are similar in kind: it applies before nonlow front vowels, but with a great many lexical exceptions.

2. *The declension of plural nouns in Czech.*⁴

Modern Czech has in its synchronic inventory of vowels a special

⁴We are grateful to Ivona Kucerova for drawing our attention to the Czech facts and for sharing with us her ideas on the proper analysis of these facts, which are explored in her 2004 manuscript.

In the examples, the surface forms are given in the official Czech orthography, while the underlying structures are given in a morpho-phonemic transcription. Capital /U/ and /I/ stand for the two yers of the language, /y/ is the [+high, +back, -round] vowel which in Czech surfaces as /i/.

set of abstract vowels called yers. Yers surface as /e/ if followed by another yer⁵; and are deleted elsewhere. This is expressed formally by the two rules in (14a), which stand in an Elsewhere relation:

(14a) Yer lowering:
 Structural Description: Yer C₀ Yer
 Structural Change: Yer >> [-high]

Yer deletion:
 Structural Description: Yer
 Structural Change: Yer deletes

The phonological process accounting for the most important properties of the Czech declension is the rule of vowel deletion discovered by Jakobson 1948. This rule which is stated in (14) deletes a vowel in position before another vowel, and applies throughout the language, in words of all types: verbs, adjectives and nouns.

(14) V >>> Ø in env. _____V

Rule (14) applies for all vowels, including yers.

We begin by examining the plural forms of the feminine /a/ declension illustrated in (15). All nouns in Czech contain a theme vowel, positioned between the stem and the case-number ending. There are two properties of this theme vowel worth immediate mention. The first is that its form may often vary, depending on properties of the stem and the case-number environment. Thus, in general, all feminine stems have the theme vowel -a-, except when they end in a palatalized consonant, in which case it is -e-. As seen, however, by the action of the rule in (14), this theme vowel will delete when followed by a vowel-initial case-number suffix.

(15)	Surface forms		Underlying representations	
Nom/Acc	žen-y	růž-e	žen-a-Y	ru:ž-e-Ø
Gen	žen	růž-í	žen-a-U	ru:ž-e-U
Dat	žen-á-m	růž-í-m	žen-a-mU	ru:ž-e-mU
Loc	žen-á-ch	růž-í-ch	žen-a-xU	ru:ž-e-xU

⁵We posit two distinct underlying yers since only one of them participates in other phonological rules such as palatalization.

Inst žen-a-mi růž-e-mi žen-a-mi ru:ž-e-mi

Since the surface forms are subject to the vowel deletion rule (15), the underlying strings for the stem of the noun žen-a 'woman' is

žen-a

where the stem is followed by the theme vowel /a/. The theme vowel surfaces in the Dat, Loc, and Inst forms. In the Nom, Acc and Gen the theme vowel is deleted by Jakobson's rule (14) because it is followed there by a vowel. Thus, as argued in Bailyn & Nevins (2004) for Russian, what looks like a morphological truncation rule in the Genitive Plural (a type of exponence argued not to exist in Harley & Noyer (1999) can be analyzed instead as phonological truncation: the exponent for the Genitive Plural is a yer, which is a vowel, and hence triggers (14). In the remainder of the discussion, we will provide independent evidence for the presence of yer in the Genitive Plural.

When the word-final vowel is Yer; it does not surface, but leaves a trace of its existence. In (15) the theme vowel is long in the Dative and Locative but short in the Instrumental. We account for this by rule (16), which lengthens [-high] vowels before a word-final Yer, as stated in (16).

(16) [V, -high] → V: in env. ---C₀ Yer #

It is this rule that accounts for the length of theme vowel in the Dative Plural and Locative Plural of *žen-a*, and for the absence of this length in the Instrumental Plural.

In order to obtain the endings of the palatal stem růž-e we must posit that in these stems (all of which end with a palatal consonant) the theme vowel is not /a/ but rather /e/. Moreover, we posit that Nom/Acc ending is /Ø/ rather than /y/ for stems whose theme vowel is /e/.

The Instrumental form falls out predictably, but there are a number of puzzles with respect to the Dative, and Locative forms, which thus far are predicted to be *růže:m* and *růže:ch*. These forms motivate the additional rule (17) of Vowel Raising, which is ordered after the lengthening rule (16) and turns long mid vowels into [+high]; i.e., [u:,i:].

(17) [V:, -low] >>>> [+high]

As a consequence of the Raising rule in (17) the outputs PlDat.

ruž-i-m and PlLoc. ruž-i-ch, obtain, where the theme is subject to Raising, but PlInstr. ruž-e-mi, where Lengthening does not apply.

The introduction of the Raising rule poses a question about its ordering. We know that it must be ordered after the Lengthening rule (16), as the theme vowel, by virtue of undergoing lengthening, is eligible for raising. Moreover, we know that Lengthening is independent of Raising, because the theme vowel /a/ lengthens but does not raise. The ordering of lengthening before raising can be derived by intrinsic Elsewhere ordering. Lengthening rules are context-sensitive. All long mid vowels that are in a pre-Yer syllable will clearly satisfy both (16) and (17). However, long mid vowels not in a pre-yer syllable will satisfy (16), but will satisfy (17). Hence (16) is more specific and must therefore be ordered before (17).

The ordering of Raising rule relative to Vowel Deletion (14) still remains open. Since long vowels delete just as well as short vowels, vowel deletion can be ordered after (17), and as we now show, this provides an explanation for the PlGen form of both palatal and nonpalatal stems.⁶ The derivation of nonpalatal stems is straightforward as shown in (18a). The derivation of palatal stems, shown in (18b), requires the additional assumption that the PlG forms are exceptions to Vowel deletion:

(18)	žen-a-U	ru:ž-e-U
Pre-Yer Length (16)	žen-a:-U	ru:ž-e:-U
Vowel Deletion (14)	žen-U	marked exception
Vowel Raising (17)	not applicable	ru:ž-i:-U
Yer deletion	žen	ru:ž-i:

The reason for ordering Lengthening (16) before Vowel Deletion is that only with this ordering can we account for the fact that the stem vowel in the PlG žen is short. As shown in (19) if the order is reversed the incorrect [ži:n] is derived; although the change in rule order does not affect the form [ru:ž-i:].

(19)	žen-a-U	ru:ž-e-U
Vowel Deletion (14)	žen-U	marked exception

⁶We owe this observation to Donca Steriade.

Pre-Yer Length (16)	že:n-U	ru:ž-e:-U
Vowel Raising (17)	ži:n-U	ru:ž-i:-U
Yer deletion	ži:n **	ru:ž-i:

It is worth taking a step back at this point and emphasizing the role of exceptions. As all stems ending with palatal consonants are exceptions to Jakobson's rule, they enable the theme vowel to be lengthened by the pre-Yer lengthening rule (16). Lengthening then feeds raising in the case of mid vowels. Finally, word-final yer deletes. Thus, by marking forms such as *ru:ž-e* as exceptions to Jakobson's rule, the otherwise regular phonology delivers a number of surprising consequences.

Before discussing length variations of the stem vowel in the concluding section of this paper, we review the plural forms of nouns that belong to declension classes than those reviewed to this point. In (20) we present the plural forms of the feminine nouns from the other declension, kost 'bone' and píseň 'song'.

(20)	Surface forms		Underlying representations	
Nom/Acc	kost-i	písn-ě	kost-I-i	pi:sIŇ-e-Ø
Gen	kost-í	písn-í	kost-e-U	pi:sIŇ-e-U
Dat	kost-em	písn-ím	kost-I-mU	pi:sIŇ-e-mU
Loc	kost-ech	písn-ích	kost-I-xU	pi:sIŇ-e-xU
Inst	kost-mi	písn-ě-mi	kost-I-mi	pi:sIŇ-e-mi

Since the stem of píseň like that of růže ends in a palatal consonant, it takes the same theme vowel /e/ and case endings as růže (cf. (15)). We recall, that in the PlG růže is an exception to Vowel Deletion and as a result the form ends with long /i:/. The same is true of the PlG of píseň, as well of the PlG of kost.

An examination of the other case forms of kost shows, however, that these differ from those of píseň. This difference is readily accounted for by positing that in the forms other than PlG kost has Yer /I/ rather than /e/ as its theme vowel. The Yer theme vowel, which is [+high] and is therefore not subject to Lengthening (17), will surface as /e/ when followed by Yer in the next syllable (cf. PlDat and PlLoc), but will delete elsewhere (cf. PlInst).

Variations in the theme vowel are also encountered in the non-feminine nouns, as shown in the examples in (21).

(21)		Masculine Gender			Neuter Gender	
Nom	hrad-y	stroj-e	pán-i	muž-i	měst-a	moř-e
Acc	hrad-y	stroj-e	pán-y	muž-e	měst-a	moř-e
Inst	hrad-y	stroj-i	pán-y	muž-i	měst-y	moř-i
Gen	hrad-ů	stroj-ů	pán-ů	muž-ů	měst	moř-í
Dat	hrad-ům	stroj-ům	pán-ům	muž-ům	měst-ům	moř-ím
Loc	hrad-ech	stroj-ích	pán-ech	muž-ích	měst-e-ch	moř-ích

here the theme vowel surfaces in the form of a long /u:/ in the PlGen and PlDat, we can be sure that the theme vowel is /o/ and subject to the lengthening rule (16) and the raising rule (17). Where long /i:/ appears on the surface, the same rules apply, but the theme vowel is /e/. Moreover, in the PlGen the deletion rule (14) does not apply except in the neuter noun of the penultimate column, where deletion does take place.

There is little to be said about the PlNom, PlAcc, and PlInst because these case endings begin with a vowel and as a result their theme vowel is deleted and cannot be determined. The exponents of the cases vary somewhat depending on the gender of the noun and also on whether or not the stem ends with a palatal consonant. The PlGen moř-í PlDat moř-ím and PlLoc moř-ích require underlying theme vowel /e/. We find this holds true of all nonfeminine stems ending with a palatal consonant. Stems that don't end with a palatal posit the theme vowel /o/, which is not lengthened by rule (16).

In addition to length variations in the theme vowel there are also length variations in the stem vowel.

There are both pairs where the stem in the NomSg is short but in the GenPl it is long, and vice-versa. Importantly, these alternations are not due to the Lengthening in (16), but are rather the consequence of readjustment rules.

According to Gladney 2002 there are 22 Czech nouns that show lengthening of stem vowels in case forms ending with yer, i.e. PlGen or SgNom.

(22)		
boh-a	bu:h	'god'
domu	du:m	'house'
hnoj-e	hnu:j	'manure'
hrach-u	hra:ch	'pea'
klihu	kli:h	'glue'
koňe	ku:ň	'horse'
loje	lu:j	'lard'
dola	du:l	'mine'
dvoru	dvu:r	'courtyard'
chleba	chle:b	'bread'
hole	hu:l	'staff'
kolu	ku:l	'stake'
lihe	li:h	'alcohol'
nože	nu:ž	'knife'

prahu pra:h 'threshold'	postu pu:st 'fast'
sněhu sni:h 'snow'	solí su:l 'salt'
stolu stu:l 'table'	větru vi:tr
vola vu:l 'ox'	vozu vo:z 'wagon'

In addition to lengthening, the stem vowel is also raised if it is [-low], as required by the raising rule (17). The examples in (22) clearly raise the question as to the proper account of stem vowel lengthening. It would appear that we have here two options. On the one hand, we could posit a Readjustment rule that lengthens the stem vowel in SgNom in the 22 nouns listed in (22).

Support for the proposition that the examples in (22) are instances of a Readjustment rule is provided by the 45 nouns in (23) (fem or neut in gender), which, according to Gladney, shorten the stem vowel in the PlG.

(23)	
bi:da běd 'hardship'	*bla:na blan 'membrane'
*bra:na bran 'gate'	bouda bud 'shed'
*ča:ra čar 'line'	di:lo děl 'work'
di:ra děr 'hole'	*dra:ha drah 'road'
houba hub 'mushroom'	hrouda hrud 'clod'
chva:la chval 'praise'	chvi:le chvil 'moment'
ja:dro jader 'core'	ja:ma jam 'pit'
ja:tra jater 'liver'	jme:no jmen 'name'
*kra:va krav 'cow'	kroupa krup 'grain'
*ku:ra kor 'bark'	*ku:že kož 'skin'
le:to let 'summer'	*li:pa lip 'linden tree'
louka luk 'meadow'	*lži:če lžič 'spoon'
*mi:ra měř 'measure'	mi:sa mis 'bowl'
moucha much 'fly'	mra:za mraz 'frost'
*pa:ra par 'steam'	peni:ze peněž 'money'
pe:ro per 'pen'	*pli:ce plic 'lungs'
pra:ce prac 'work'	ra:na ran 'blow'
*si:la sil 'force'	*ska:la skal 'cliff'
sli:va sliv 'plum'	touha tuh 'longing'
tra:va trav 'grass'	trouba trub 'trumpet'
*va:ha vah 'scale'	*vra:na vran 'crow'
za:da zad 'back'	*ža:ba žab 'frog'
*ži:la žil 'vein'	

The alternations in (23) are not the exact mirror image of those in (22). In particular, the diphthong /ou/ alternates with short /u/. We account for this by noting that since Shortening is due to a Readjustment rule its effects are introduced into the derivation before all phonological rules apply. Alternations such as ku:r-a kor 'bark' are then accounted for by positing as underlying the stem /ko:r/. This is shortened in the PlGen,

giving as the correct output /kor/ with short /o/.

Alternations such as boud-a bud, on the other hand, are explained by positing a phonological rule of u-diphthongization (24) and ordering it before the Raising rule (17).

(24) /u:/ >>> /ou/

Stems like /le:t-o/ 'summer', /jme:no/ 'name', /pe:r-o/ 'pen' must be marked, in addition, as exceptions to the raising rule (17).

Gladney observes that the 18 items marked with an asterisk in (36) shorten the stem vowel not only in the PlGen but also in the SgInst and in all oblique cases of the Plural; the rest of the items shorten the vowel only in the PlGen.

The 18 items that do undergo lengthening in the rest of the Plural oblique forms conform to what Scheer calls a "trimoraic template", which shortens all vowels when there are two mora in the case+number ending.

In this section we have examined three morphophonemic processes affecting the length of vowels. One of the three is a phonological rule which lengthens vowels in position before word final yer. The other processes is a Readjustment rule applies to the nouns in (24) and shortens the stem vowel in the PlG (and sometimes also in other oblique cases of the plural and in the SgInstr, in addition.) Since Readjustment rules are ordered before all phonological rules, these Readjustment determine the input to the phonological derivation. The case for treating alternations in stem length by means of Readjustment rules is strengthened further by the many additional facts about Czech quantity alternations reported in Scheer 2003. It is noteworthy that neither Scheer, nor Gladney discuss the phonological rule of vowel lengthening before word-final Yer, illustrated in (27).⁷

4. Conclusion

We have explored two examples of sequenced phonological computation that illustrate the principles of rule-ordering and

⁷Among the problem to be investigated next is the counterpart of the Czech lengthening processes in other Slavic languages. It is obvious that in the East Slavic languages the PlG is subject to a Readjustment rule that inserts the glide y/w before the Yer of the case ending. The PlG in other Slavic languages is a mixture of the East Slavic glide insertion and the Czech vowel lengthening processes.

rule-exceptions. A number of open research questions remain, such as the principles by which rule-ordering is determined and the lexical representation of exceptions. It is our hope that the remarks offered here will inspire future research into both of these matters.

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