A Stratal OT perspective on vowel harmony

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18.1 Assumptions and predictions

18.1.1 Stratal OT

In stratal models of grammar, phonology and morphology operate in the lexicon at the stem level and at the word level, outputting words which are syntactically combined and then subjected to postlexical phonology. The constraint-based version, Stratal Optimality Theory (SOT), treats each level as a parallel OT constraint system. It derives opaque interaction among phonological constraints from interlevel seriality and from the cyclic interleaving of phonology with morphology within strata. Since the constraints at each stratum are limited to the well-understood markedness and faithfulness constraint families, the major results of OT about factorial typology are retained, and the system is formally clean like classical OT.

This chapter offers a review of some predictions that SOT makes about vowel harmony, and a survey of the part of the empirical landscape that puts those predictions to a test, centering on the domains and levels within which harmony operates and on its directionality. After outlining the theoretical assumptions I take up the distinction between roots and stems and the direction of harmony, the consequences of cyclic assignment of harmonic features, and abstractness and derivational opacity. I conclude with a more detailed analysis of Yowlumne Yokuts rounding harmony in the context of the language's phonology and morphology, which puts the theory through its paces.

I presuppose an approach to morphology that recognizes morphemes and morphological constituency. For concreteness I assume Minimalist Morphology (MM, Wunderlich 1994, 1996, 2001; Stiebels 2006), a constructional (generative, lexicalist) morpheme-based approach in which morphology incrementally merges stems and affixes, and assembles at each step the morphosyntactic, phonological, and semantic properties of the resulting combinations from the properties of their parts at each step, feeding fully interpreted words to the syntax. This theory predicts the cyclicity of lexical phonology, the sensitivity of phonological affix selection to cyclically derived representations, the locality and inward sensitivity of morphological selection, and the Mirror Principle. However, I believe that almost everything here is also compatible with Distributed Morphology (DM).

18.1.2 Harmony constraints

Vowel harmony presents special challenges for phonology because of its long-distance character and its interaction with word structure. It can operate in three principal ways: cyclically from the innermost constituent outwards, from any vowel with the dominant feature value to all others, and directionally rightwards or leftwards within a word or a subconstituent of it. Like all phonology, it negotiates the conflicting claims of faithfulness constraints and syntagmatic and paradigmatic markedness constraints. We can model the processes and circumscribe their typology with the following constraints:

(1) a. Faithfulness constraints:
(i) Max[μF],
(ii) Ident-Stem(F),
(iii) Ident-σ_1(F)... (positional faithfulness, Beckman 1997).
Input [αF] does not correspond to output [–αF], (i) where [αF] is the marked value of F, (ii) where [αF] is in a stem, (iii) where [αF] is in an initial syllable.

b. Syntagmatic markedness: *[αF][–αF]
An [αF] vowel is not followed by a [–αF] vowel.

c. Paradigmatic markedness constraints (minimization of segment complexity):
(i) *[αF], (ii) $*\begin{bmatrix}\alpha\mathrm{F}\\ \beta\mathrm{G}\end{bmatrix}$, where αF is the marked value of F.
A segment does not have these marked feature specifications.

The constraint Max[+ATR] (an input [+ATR] must correspond to an output [+ATR]) has been motivated for vowel harmony by Archangeli & Pulleyblank 2002; Max(+Back) by Coetzee 2006; on Max[F] in general see Lamontagne & Rice 1995; Causley 1997; Wheeler 2005. The general idea is that markedness is privileged visibility to constraints; thus each faithfulness constraint that applies to the feature F has a counterpart that applies specifically to the marked value μF (Kiparsky 1994).

Such asymmetrical constraints capture at least some of the advantages of unary and particle-type systems of representation without abandoning the binarity of features. They play a major role in harmony systems.

(1b) *[αF][–αF] is satisfiable by [αF][αF] or by [–αF][–αF], as decided by faithfulness constraints like (1a). I assume that (1b) is a strictly local constraint which is not violated if another vowel, another instance of [F], or another element linked to [F] intervenes.

This constraint system, implemented in Stratal OT, is intended to replace harmony-specific machinery such as global Agree (Baković 2000; McPherson & Hayes 2016; McCollum & Essegbey 2020), Spread (Kaun 1995), Share (in Harmonic Serialism, McCarthy 2011), target-centric Search-and-Copy (Nevins 2010; Ozburn 2019), extensions of Correspondence Theory such as ATB (Krämer 2003; Rose & Walker 2004; Rhodes 2012), as well as the theoretically problematic Align family of constraints (Ringen & Kontra 1989; Cole & Kisseberth 1994; Pulleyblank 1996; McCarthy 2004); on these see Chapter 30, this volume.

Together, faithfulness to dominant feature values (1a) and the local harmony constraint (1b) make two desirable predictions. First, an output in which the dominant feature value spreads always prevails over the output in which its recessive counterpart spreads, regardless of which has more Ident-[F] violations. Secondly, when Agree is necessarily violated due to invariant opaque vowels, they predict that the dominant feature value spreads to the maximal extent. Systems based on symmetric Ident and global Agree fall short on both these counts. They wrongly predict, first, that among outputs that fully satisfy Agree, the one with fewer Ident violations is optimal (the "Majority Rule" problem, Baković 2000), and secondly, that a feature either spreads entirely throughout a domain or not at all (the "Sour Grapes" problem), Padgett 1995; Wilson 2000, 2003; McCarthy 2004.

Maasai (Nilotic) illustrates how (1) avoids these pathologies. It has both leftward (regressive) [+ATR] harmony to which [–ATR] /a/ is opaque, and rightward (progressive) [+ATR] harmony that changes /a/ to [+ATR] /o/ and proceeds across it (Guion et al. 2004). They are driven by distinct constraints (Quinn-Wriedt 2013; cf. Walker 2011). In the first derivation of (2), underlying /ɪ-mor-ɪʃɔ/ has both [+ATR] and [–ATR] vowels but no opaque /a/. Two outputs fully satisfy Agree: *[ɪmɔrɪʃɔ], where all vowels are [–ATR], and [imoriʃo], where all vowels are [+ATR]. Of these, Ident(ATR) incorrectly selects the former, because it has fewer Ident(ATR) violations (an instance of the Majority Rule problem). Max(+ATR), on the other hand, correctly selects the latter output, which preserves the marked feature value [+ATR].

(2)

	Max[+ATR]	*ə	*[+ATR][–ATR]	Ident(Rd)	$*\begin{bmatrix}-\text{ATR}\\-\text{Low}\end{bmatrix}$[+ATR]
Input: /ɪ-mor-ɪʃɔ/					
1a. *ɪmorɪʃɔ			*		
1b. *ɪmɔrɪʃɔ	*				
1c. ☞ imoriʃo					
Input: /nɛ-mɑ-nʊk-ie/					
2a. ☞ nɛmɑnukie					
2b. *nɛmɑnʊkie					*
2c. *nemənukie		*			
2d. *nɛmɑnʊkɪɛ	*				
Input: /puk-ɑ/					
3a. *pukɑ			*		
3b. ☞ puko				*	
3a. *pukə		*			
3d. *pʊka	*				

In (2a-d), /nɛ-mɑ-nʊk-ie/ has a sequence of opaque /a/, [–ATR] /ʊ/, and [+ATR] /i/. Since /a/ interrupts leftward harmony, the output will begin with the sequence [nɛmɑ. . .], which violates Agree. Ident(ATR) now predicts the wrong output [*nɛ-mɑ-nʊk-ie], rather than the correct [nɛmɑnukie], which ties on Agree but is more faithful overall (an instance of the Sour Grapes problem). Constraint system (2), which is the simplest that conforms to (1) and generates Maasai's regressive and progressive harmony patterns, predicts the right outcome.

Finally, in the derivation (3a-d) the input /puk-ɑ/ has /a/ to the right of a [+ATR] vowel. Since /ə/ and /ɤ/ are not in Maasai's phonemic repertoire, harmony converts /a/ to the closest available [+ATR] vowel, which is /o/.

18.2 Roots, cyclicity, and the direction of harmony

18.2.1 Roots, stems, and directionality

Since bound roots are not cyclic domains,[1] stem faithfulness will not dictate directionality in a root+affix combination, and each constituent can harmonize with a marked feature of the other. This yields a hitherto unrecognized mixture of dominance and stem-outward harmony documented below. The pattern is that roots combine with their first affix in dominant-recessive fashion, outputting a derived stem which then cyclically passes the harmonic feature outward to subsequently added affixes by stem faithfulness.

18.2.2 Nen

First, a simple example of morphologically governed bidirectional harmony. Nen (Tunen, Bantu) has an underlying 10-vowel system with distinctive ATR, which is reduced to an 8-vowel system by the lowering of high [–ATR] /ɪ,ʊ/ to mid [+ATR] /e,o/ (Stewart & van Leynseele 1979). Bound noun class prefixes impose their own [+ATR] feature on the bound pronouns they combine with, and themselves take on the ATR value of their nominal stems (Dugast 1971; Mous 2016; McCollum & Essegbey 2020). For example, in (3) the class prefix /mu-/ and its plural counterpart /mi-/ impose their [+ATR] feature on the demonstrative pronoun /-tana/, but in turn acquire the [–ATR] features of the nominal stem /laŋ/ that they combine with:

(3) a. /mú-tana mù-laŋ/ mútə̀nə mòlaŋ 'just this story'
b. /mí-tana mì-laŋ/ mítə̀nə mèlaŋ 'just these stories'

Assuming as before that bound functional elements (in this case bound pronouns as well as class prefixes), are not stems on their own, and therefore not harmony domains, the output is derived by the ranking (1b) *[+ATR][–ATR] > (1a.ii) > (1a.i). In (4a), the dominant constraint (1a.ii) spreads the stem's [–ATR] feature to the prefix; in (4b), (1a.ii) yields a tie, which (1a.i) resolves in favor of the spread of the marked feature value.

(4) a. [[mù-[laŋ]$_N$]$_N$ → [[mù-[laŋ]$_N$]$_N$ by Ident-Stem(F)
+A–A −A
b. [mú-tana]$_N$ → [mú-tənə]$_N$ by Max[μF]
+A −A +A

18.2.3 Warlpiri

Warlpiri, a Pama-Nyungan language of Australia, has three vowels *i, a, u*. Harmony limits the co-occurrence of *i* and *u* within stems, and generates alternations between them in suffixes, enclitics, and verb roots. It is both progressive (left to right) and regressive (right to left), depending on morphology (Hale 1973; Nash 1979, 1980; Harvey & Baker 2005; Zentz 2011). In both directions, *i*:*u* harmony is blocked by intervening opaque *a*, but it differs in the following respects:

(5)

	Progressive Harmony	*Regressive harmony*
a.	Applies rightwards from (free) stems to suffixes.	Applies leftwards from suffixes to roots.
b.	*a* is opaque and selects *u*.	*a* is opaque and selects *i*.
c.	The non-alternating high vowel is *i*.	The non-alternating high vowel is *u*.
d.	Labials block harmony.	Labials are transparent.

[1] Roots are then bound and need not be exhaustively syllabifiable or obey prosodic minimality conditions. See Inkelas (1989) for the principle and its theoretical grounding in Prosodic Lexical Phonology, and Kiparsky (1982); Harris (1983); Hargus (1988); Itô & Mester (2003) for empirical evidence. However, Mohanan (1989) posits a root cycle for Malayalam.

I'll argue that progressive and regressive vowel harmony manifest a single constraint (6).

(6) $*\begin{bmatrix}-\text{Round}\\+\text{High}\end{bmatrix}\begin{bmatrix}+\text{Round}\\+\text{High}\end{bmatrix}$

Regressive harmony labializes a sequence of *Ci* syllables at the end of verb roots before an immediately following *Cu*:

(7)

			-rnu (Past)	*-rni* (Nonpast)	*-ka* (Imperfect)
a.	/pangi/	'dig'	pangu-rnu	pangi-rni	pangi-ka
b.	/kiji/	'throw'	kuju-rnu	kiji-rni	kiji-ka
c.	/yirra/	'place'	yirra-rnu	yirra-rni	yirra-ka
d.	/yurrpa/	'grind'	yurrpa-rnu	yurrpa-rni	yurrpa-ka
e.	/nyunji/	'kiss'	nyunju-rnu	nyunji-rni	nyunji-ka
f.	/kipi/	'winnow'	kupu-rnu	kipi-rni	kipi-ka

Disyllabic roots can have the vowel combinations in (8):

(8) attested: a…a i…a u…a unattested: *a…u *i…u *u…u
a…i i…i u…i

Rounding is thus non-distinctive in root-final sequences.

In nominal stems rounding is distinctive. They trigger *progressive i∼u* harmony, where *a* patterns with *u* in selecting *u*, rather than *i* as in (7c, d).

(9)
a. maliki-kirli-rli-lki-ji-li 'dog-Prop-Erg-then-me-they'
b. kurdu-kurlu-rlu-lku-ju-lu 'child-Prop-Erg-then-me-they'
c. minija-kurlu-rlu-lku-ju-lu 'cat-Prop-Erg-then-me-they'

Progressive harmony is blocked by intervening labial consonants, so that endings beginning with *pu-* and *wu-* (there are none with *mu-*) have a fixed *u*. In contrast, regressive harmony crosses labial consonants, as in (7f).

(10)
a. ŋamirni-puraji 'your (maternal) uncle'
b. ŋali-wurru '12-Emphatic', 'you and I are the ones'

The non-alternating vowel in regressive harmony is *u*, as in the first syllable of /nyunji/ (7f), versus alternating /kiji/ (7b), whereas in progressive harmony it is *i*, which occurs in suffixes and clitics with fixed *i* in the first syllable, e.g.:

(11) *-pinangi(w)* 'only, any', *-pinki* 'etc.', *-kirli* 'exactly' *-yi* 'continuative' (Nash 1979: 83, 96).

That verbal roots are not cyclic constituents in Warlpiri was already proposed by Nash (1979) because they differ morphologically from noun stems:

(12)

	Nominals	*Verbs*
inflection type	agglutinating	inflectional (fusional)
boundness	occur uninflected	require inflection
inflection	uniform (no "declensions")	five "conjugations"
number of items	thousands	just over a hundred roots
constituency	[Noun-Noun]-inflection	Preverb-[Verb-inflection]

Nash also noted that vowel harmony applies *before* reduplication in verbs (e.g., *pangu-pangu-rnu* 'dig quickly-Past' vs. *pangi-pangi-rni* 'dig quickly-NPast'), but *after* reduplication in nouns. Indeed, noun reduplication never includes inflectional affixes, while verb reduplication can (Nash, p. 182, 141). I conclude that reduplication operates on bare Noun stems and suffixed verbal stems, but not on bare Verb roots.

We require three constraints, respectively instantiating (1a.i-ii) and (1b), ranked as follows:

(13) *[–Round][+Round] (= (1b)) > Ident-Stem(Round) (=(1a.ii)) > Max[μF] (= (1a.i))

A root with its first suffix makes a stem. (1b) imposes rounding harmony on it. The rounding feature of each stem vowel is however protected by the faithfulness constraint (1a.ii) Ident-Stem(Round). If no other constraint were applicable, the disharmonic root+suffix combination would surface unchanged. However, (1a.i) Max[+Round] acts as a tie-breaker and spreads the rounding from a rounded suffix vowel to the root vowel.

Nouns, being free forms, are inherently stems. Under the ranking (1aii) > (1ai), their vowels prevail over the suffix vowels, with the consequence that violations of the harmony requirement (1b) are resolved by delabialization (M = Morphology).

(14) $[\text{maliki}]_{\text{N}} \xrightarrow{\text{M}} [[\text{maliki}]_{\text{N}}\text{-kurlu}]_{\text{N}} \xrightarrow{(6),(1\text{aii})} [[\text{maliki}]_{\text{N}}\text{-kirli}]_{\text{N}}$

The low vowel *a* is neutral and triggers neither labialization nor delabialization (property 5b); thus the rounding harmony constraint (6) is restricted to high vowels.

(15) $*\begin{bmatrix}-\text{Round}\\+\text{High}\end{bmatrix}\begin{bmatrix}+\text{Round}\\+\text{High}\end{bmatrix}$

In stems formed by adding a suffix to mixed-vowel roots like *nyunji* 'kiss', rounding does not spread forward from *u* to *i*. For example, the forms (7e) *nyunji-ka*, *nyunji-rni* do not violate (6) or any other markedness constraint that dominates faithfulness. Rounding does spread backward in /nyunji-rnu/ → *nyunju-rnu*, for **nyunji-rnu* would violate (6) and **nyunji-rni* would violate (1ai) Max(+Round).

(16)

	$*\begin{bmatrix}-\text{Rd}\\+\text{High}\end{bmatrix}\begin{bmatrix}+\text{Rd}\\+\text{High}\end{bmatrix}$	Id-Stem[Rd]	Max[+Rd]
Input: $[\text{ kiji - rnu }]_{\text{VStem}}$			
1a. kiji - rnu	*		
1b. ☞ kuju - rnu		*	
1c. kiji - rni		*	*
Input: $[\,[\text{ maliki }]_{\text{NStem}}\text{ kurlu }]_{\text{NStem}}$			
2a. maliki - kurlu	*		
2b. maluku - kurlu		*	
2c. ☞ maliki - kirli			*
Input: $[\text{ nyunji - rnu }]_{\text{VStem}}$			
3a. nyunji - rnu	*		
3b. ☞ nyunju - rnu		*	
3c. nyunji - rni		*	*
3d. nyinji - rni		*	*

Property (5c) follows trivially, for progressive harmony, being unrounding, has no effect on vowels that are already unrounded underlyingly, and regressive harmony, being rounding, has no effect on vowels that are already rounded underlyingly.

Property (5d), that labial consonants block progressive harmony, can be accounted for by assuming that labial consonants are specified for the rounding feature. (6) is a local constraint which is not violated if a consonant linked to the harmonic feature intervenes between the triggering voeel and target. The labial therefore blocks the leftward spread of harmony.

(17) $[\text{ŋali}]_{\text{N}} \rightarrow [[\text{ŋali}]_{\text{N}}\text{wurru}]_{\text{N}}$

–R   –R +R +R

For the same reason, underlying sequences of the form /iPu/ in words like *pipipuka* 'bereaved father', *yirriwu* 'Acacia ancistrocarpa', *wajirrki-puru* 'during the wet time' do not violate (6). As for why labial consonants do not block regressive harmony, we can suppose that labial consonants only get specified with a value for the feature [Round] before a following [+Round] vowel, bleeding harmony.

(18) a. [[ŋali]$_N$wurru]$_N$
−R +R +R

b. [wajirrki - puru]
−R −R +R

Suffixed roots are stems; as predicted, they induce *progressive* harmony:

(19) a.	/wanti-mi-juku/	wanti-mi-jiki	'fall-still'
b.	/ya-nu-juku/	ya-nu-juku	'went-still'
c.	/wanti-ja-juku/	wanti-ja-juku	'fell-still'

The inceptive is built on the non-past verb root with the inceptive suffix followed by another Non-Past suffix (Harvey & Baker 2005: 1469). It looks like a verb followed by an inflected inceptive auxiliary.

(20) a. Past: kúju-rnu-njù-nu 'went and threw'

b. Non-Past: kíji-rni-njì-ni 'goes and throws'

c. Imperative: kíji-rni-njì-ngka ∼ kíji-rni-njì-nta 'go and throw!'

d. Future: kíji-rni-njì-nki 'will go and throw'

The derivation is /kiji - rnu/ → [kúju-rnu]$_V$ by leftward harmony as in (16a), and on the next cycle [kúju-rnu]$_V$ -nji-ni]$_V$ → [kúju-rnu-njì-ni]$_V$ by rightward harmony as in (16b), exactly as the analysis predicts.

Because affixation turns a root into a stem, regressive harmony happens only in the innermost, noncyclic root layer of verb morphology, where it is obligatory. There is one exception: in some dialects, immediate future suffixes, though ostensibly added directly to roots, undergo *progressive* vowel harmony, just like clitics and noun suffixes. A solution (purely technical for now but potentially testable by morphological evidence) is that they subcategorize for verb stems formed by a null suffix, rather than bare roots.

Both regressive rounding and progressive unrounding are essentially exceptionless. Warlpiri also has two more marginal sets of cases where *i* undergoes progressive rounding harmony to *u*: epenthetic vowels in loanwords (21a), and, in some dialects and with idiolectal variation, clitics (21b) (Harvey & Baker 2005: 1460).

(21) a. *yarti* 'yard', *turaki* 'truck', *majini* 'machine', but *nanikutu* 'nannygoat', *puluku* 'bullock', *miyurlu* 'mule'.

b. /=rni/ 'hither': *wararrku=rnu parnka-ja* 'it slithered hither' (cf. *pina=rni ya-nu* 'he came back hither'), /=rli/ '1 Du.Excl.': *kuyu=rlu nga-rnu* 'you and I ate the meat' (cf. *minija=rli nya-ngu* 'you and I saw the cat'), and some other person-marking clitics.

In some dialects/idiolects the clitics in (21b) have invariable /i/, like the items in (11). In others they harmonize with a preceding *u* (Harvey & Baker 2005: 1460). These cases of progressive rounding harmony are derivable by generalizing the harmony constraint (15) to (22).

(22) $*\begin{bmatrix}\alpha\text{Round}\\+\text{High}\end{bmatrix}\begin{bmatrix}\alpha\text{Round}\\+\text{High}\end{bmatrix}$

Since the progressive spread of rounding (as opposed to the progressive unrounding triggered by (15)) is reportedly restricted to clitics and to epenthetic vowels inserted at the ends of loanwords, the generalization to (22) that drives it is perhaps confined to the postlexical phonology.

18.2.4 Telugu

The vowel harmony system of modern colloquial Telugu (a Dravidian language) resembles Warlpiri's. Telugu has five vowels *a, e, i, o, u*, with distinctive length, marked here with a macron, in accord with the sources cited. It has both regressive harmony, by which root vowels harmonize with a following suffixal vowel, and progressive vowel harmony, which applies elsewhere (Ramarao 1976; Sastry 1987).[2]

[2] It also has a distinct tenseness harmony process (Wilkinson 1974).

Regressive harmony assimilates short unstressed (=non-initial) syllables of verb roots to the first suffixal vowel (Sastry 1987: 190, 221).[3]

(23)	a.	/kudurcu-u/	kudurcu	'arrange!'
	b.	/kudurcu-i/	kudirci	'having arranged'
	c.	/kudurcu-aka/	kudarcaka	'don't arrange!'

Regressive harmony process also takes place before the innermost nominal suffix, plural *-lu*.[4]

(24)	a.	/gadi-lu/	gadulu	'rooms'
	b.	/kolimi-lu/	kolumulu	'hearths'
	c.	/enimidi-lu/	enumudulu	'eights'

That the plural suffix *lu* (24) induces regressive harmony suggests that Telugu (unlike Warlpiri) has a root layer for nouns, at which the plural is added. This is consistent with the fact that *lu* is the innermost noun inflection and always precedes the case endings.

Regressive harmony is blocked by alveolar or retroflex consonants *r*, *l*, *ṭ*, *ḍ* in the final or prefinal syllable (25a,b) and by a preceding *y* (25c,d) (Sastry 1987: 186).

(25)	a.	/māmiḍi-lu/	māmiḷḷu	'mangoes'
	b.	/penimiṭi-lu/	penimiṭlu	'husbands'
	c.	/payiru-lu/	pay(i)rulu	'crops'
	d.	/poyyi-lu/	poy(yi)lu	'ovens'

In the outer layer of verb morphology (person/number suffixes) and in the nominal system (case suffixes), harmony is progressive (Sastry 1987: 164 ff.). These inflections alternate between *i* after *i* and *u* elsewhere (Ramarao 1976: 28). As in Warlpiri, *a* is opaque.

(26)	a.	/gadi-ku/	gadiki	'to the room'
	b.	/haydarabaadu-ku/	haydarabaaduku	'to Hyderabad'
	c.	/kalapa-ku/	kalapaku	'to the lumber'
	d.	/padi mandi-mu/	padi mandimi	'we are ten persons'
	e.	/strī-nu/	strīni	'woman' (acc.), 'I am a woman'
	f.	/strī-wu/	strīwu	'you are a woman'
	g.	/rākapōti-ru/	rākapōtiri	'you did not come'
	h.	/moguḍu-i-ku/	moguḍiki	'to the husband'

The consonantal effects involving *y* and the retroflex and alveolar consonants (arguably [+Back] and [–Back] respectively) suggests that this is backness harmony; rounding is in any case not prominent and *u* is the default epenthetic vowel.

(27) $*\begin{bmatrix}-\text{Back}\\+\text{High}\end{bmatrix}\begin{bmatrix}+\text{Back}\\+\text{High}\end{bmatrix}$

In short, Telugu behaves like Warlpiri in that roots assimilate to their suffixes, suffixes assimilate to their stems, and harmony is stopped by a set of opaque consonants..

(28) a. [gadi-lu]$_{\text{Stem}}$ $\rightarrow$ gadulu 'rooms'

b. [gadi]$_{\text{Stem}}$-ku $\rightarrow$ gadiki 'to the room'

Like Warlpiri, Telugu has suffixes with invariable *i*, such as "pronominalizing" *-di* and *-wi* (Krishnamurti & Sarma 1968: 30, 37), and genitive (or "oblique") *-i*, *-ti* (Ramarao 1976: 29):

(29)	a.	a-di raamarawu-di	'that is Ramarao's'
	b.	i-di sarooja-di	'this is Saroja's'
	c.	a-wi atani-wi	'those are his'

[3] Most unaccented root vowels of Telugu are /u/ (the default vowel). Ramarao (1976) also recognizes roots with noninitial /i/ and /a/, some of which undergo total assimilation to suffixal vowels (Sastry 1987: 168, 170, 175): *caduwu* 'read!', *cadiwi* 'having read', *cadawaka* 'don't read!'; *cemarcu* 'become wet!', *cemarci* 'having become wet', *cemarcakaaka* 'don't become wet!'.

[4] In Sanskritic words, only the last vowel harmonizes, e.g., /atithi-lu/ *atithulu* 'guests', /samiti-lu/ *samitulu* 'associations' (Ramarao 1976: 27).

The blocking function of the retroflex and alveolar consonants is accounted for as in Warlpiri: when a consonant specified for [±Back] intervenes, it interrupts adjacency and (15) is not violated.

The lack of rounding after *y* (25c,d) appears to be due to a local fronting process which assimilates *u* to a preceding *y*. It is independently required by the appearance of the imperative suffix /-u/ as *i* after roots ending in *y*, as in (30c,d):

(30)	a.	amm-u	'sell'	c.	ceyy-i	'do'
	b.	kon-u	'buy'	d.	raay-i	'write'

18.3 Derivational opacity

18.3.1 Abstractness in Stratal OT

OT enforces derivational transparency by requiring constraints to be satisfied in output representations. Thereby it entails a particularly stringent version of the Alternation Condition, which disallows any covert ("abstract") phonological entities, for example "Trojan" vowels (Krämer 2003, Chapter 21, this volume), such as the underlying /ɨ/ that has been posited in Hungarian for back-harmonizing /i/. Stratal OT, however, posits that constraint rankings are level-specific, which predicts that covert phonological distinctions are possible, though they can only be active at levels that precede the level at which they are neutralized. So Trojan vowels can be active in the lexical phonology and suppressed in the postlexical phonology or in phonetic implementation, but they cannot conversely be active postlexically and suppressed in the lexical phonology. This constraint on absolute neutralization is empirically well supported, and conceptually preferable because it is an organic consequence of Stratal OT and not just an addendum to the theory that prohibits its wrong consequences.

Although Stratal OT allows derivational opacity, it imposes strict limits on its depth. Phonological systems are known to exhibit derivationally transparent (feeding and bleeding) interaction of considerable depth, but empirical studies have failed to turn up derivationally opaque (counterfeeding or counterbleeding) relations of comparable depth. There are few compelling cases of opacity exceeding a depth of two. A theory that countenances a word-level overlay on the stem level and a postlexical overlay on the word level imposes exactly that limit on the stacking of opacity. As predicted, more complex stacking of opacity is uncontroversially found only in languages with exceptionally rich multi-layered morphologies (Jaker & Kiparsky 2018, 2020).

More generally, the stem-level constraint system of a language defines its segment inventory and morpheme structure. From Stratal OT's perspective, the idea that the form of lexical entries is derivative of the stem-level phonology is the true core of Lexicon Optimization.

Derivational opacity is connected to morphology in other ways as well. It arises from cliticization and compounding, from introfixation, which can create disharmonic islands within a harmony domain (Chapter 17, this volume), and from stratal and templatic overlay, as laid out in the following sections.

18.3.2 Opaque harmony through morphological overlay

Vowel harmony may be obscured by other processes in several ways. Special templatic morphology may override even general fully productive harmony processes in their overlapping domain. In Tuvan (Turkic), a robust front/back harmony pattern is disrupted by a productive morphological process of ablaut which converts the second syllable of any adjective to *-ii* or *-ee* to express intensivity, creating disharmony if the first syllable is back, e.g., *kɨrgan* → *kɨrgeen* 'old', *čaraš* → *čariiš* 'little', *ulu* → *ulee* 'big' (Harrison 2000).

18.3.3 Opaque harmony through stratal overlay

Transparent phonology may be made opaque by processes operating at a later level. In particular, vowel harmony at the stem level when morphemes are first combined can become opaque at the word level or postlexically by word-level deletion and devocalization processes.

To begin with a simple example: in Assamese (Indo-Aryan), the [+ATR] /-i/ vowel of the future suffix /-im, -ib/ triggers [+ATR] harmony on the root (and on any preceding prefixes). The triggering vowel is then deleted after a root that ends in a vowel, leaving an apparently unconditioned tense vowel behind (Mahanta 2007).

(31)

	kɔr 'do'		rɔ 'wait'	
Imperative	/kɔr/	kɔr	/rɔ/	rɔ
Fut. 1PL	/kɔr-im/	korim	/rɔ-im/	rom
Fut. 2PL(hon), 3PL	/kɔr-ib-ɔ/	koribɔ	/rɔ-ib-ɔ/	robɔ

Luo (Nilotic) [+ATR] harmony persists even when its trigger (/o/ in (32a)) is devocalized (Swenson 2015).[5]

(32) a. /bào/ [bʌ̀o] 'board, plank', /bào-a/ [bʌ̀p-ʌ̀] 'my plank'

b. /bàɔ/ [bàɔ] 'to patch', /bàɔ-a/ [bàw-à] 'patch me'

In some dialects of Seto (Balto-Finnic), lexical back harmony is interrupted by a local postlexical fronting of ə to *e* after palatals. This creates a front vowel island with *e* in the midst of a back harmony domain (examples from Mägiste 1977).

(33) a.	*tõ-i-je*	[tõjje]	'brought'	(140)
b.	*aije-mi*	[ajjemi]	'we drove'	(48)
c.	*raśśeeja-st*	[raśśeejast]	'Russia' (ELA)	(80)
d.	*naaśe-lõ*	[naaśelõ]	'woman' (ALL)	(202)

In some Seto dialects, such as the Northern Seto of Mikitamäe, palatal fronting does not neutralize ə and *e*. These dialects have [tõjjə], [sajjə] for (33a,b) (Iva 2000: 88).

Some Tuvan dialects show essentially the same phenomenon. A palatal glide in a coda can front the nucleus to create superficial disharmony, as in *ačey* 'father', for *ačay.* In Karimojong (Nilotic) a trilled [r] causes tongue retraction as a coarticulatory effect, which in the itive (translocative) suffix has been phonologized as a [–ATR] feature that spreads approximately two syllables in both directions (Lesley-Neuman 2012).

Uyghur (Turkic) has a Turkish-type vowel system with fronting harmony and transparent neutral /i/. The vowel /i/ is also derived from harmonic /ä/ and /a/ in medial open syllables (Lindblad 1990; Vaux 2000; Mayer et al. 2022). In disharmonic stems, the raising of back *a* to neutral *i* interacts interestingly with fronting harmony, which takes place if the last non-neutral vowel of the stem is front. Vaux points out that any non-cyclic ordering of these rules gives the wrong results. Fronting before raising produces the wrong form /äswab-i-γa/ → **äswibiγa* in (34a), and fronting after raising produces the wrong form /adäm-i-γa/ → **adimiγa* in (34b).

(34) a.	/äswab/	*äswap*	/äswab-i-γa/	*äswibiγä* 'to his tool'
b.	/adäm/	*adäm*	/adäm-i-γa/	*adimiγä* 'to his man'

In a rule-based framework, fronting harmony must take effect *after* raising, because it is fed by it in (34a), and *before* raising, because it is not bled by it in (34b). Vaux resolves this contradiction by having fronting apply both cyclically and post-cyclically, ordered after raising in the non-cyclic block. In Stratal OT, this means that raising applies only at the word level, where it feeds fronting in (35a), and makes it opaque in (35b):

(35) a. Stem Level: /äswab/ $\xrightarrow{\text{M}}$ äswab-i-γa (Fronting is inapplicable)
Word Level: äswab-i-γa $\xrightarrow{\text{Raising}}$ äswib-i-γa $\xrightarrow{\text{Fronting}}$ äswib-i-γä

b. Stem Level: /adäm/ $\xrightarrow{\text{M}}$ adäm-i-γa $\xrightarrow{\text{Fronting}}$ adäm-i-γä
Word Level: adäm-i-γä $\xrightarrow{\text{Raising}}$ adim-i-γä (Fronting becomes opaque)

On this analysis, harmony spreads the marked feature value [–Back], as in Finnish.

[56] For opacity in Luo consonant harmony, see Mackenzie (2016).

18.3.4 Trojan vowels in Urhobo

"Trojan" vowels (Krämer 2003) have a harmonic value that is is the opposite of their pronunciation, like the back harmonic /iː/ of Hungarian *híd* 'bridge'. There is evidence in a number of languages that their underlying representation matches their harmonic value rather than their pronunciation, e.g., Oroch (Tungusic, Tolskaya 2014), Okpe (Edoid, Hoffmann 1973; Archangeli & Pulleyblank 1994; Hulst 2018: 334-6), and Moro (Kordofanian, Ritchart & Rose 2017). This is a welcome result, since Stratal OT cannot rule out such abstract vowels, nor absolute neutralization in general, without some ad hoc counterpart of the "Alternation Condition". Rather, the architecture of Stratal OT *restricts* Trojan vowels in a principled way: they can only harmonize according to their abstract feature value at a level prior to the one at which they are neutralized. By constraining opacity to inter-level masking, Stratal OT eliminates an empirically unjustified class of abstract absolute neutralization analyses that is allowed by both classical rule-based phonology and by parallel OT augmented with transderivational machinery.

Urhobo (Niger-Congo) has seven contrastive vowels *i, e,* ɛ*, a, u, o,* ɔ, originating from a 2x5 ten-vowel system (such as that of Kinande, Degema, Kalenjin, Koromfe, Akposso, and Mayak) by the merger of /ɪ/ and /e/ into [e], /ʊ/ and /o/ into [o], and /a/ and /ə/ into [ɛ].[7] The underlying inventory retains a ten-vowel system (36), but as a result of the merger, three of the remaining seven vowels function both as [+ATR] vowels and as [–ATR] vowels in the synchronic phonology (Aziza 2008, 2016). We distinguish the [+ATR] and [–ATR] versions of the three neutralized vowels /e/, /o/, and /ɛ/ graphically by subscripting.

(36)

	Set 1 [+ATR]		Set 2 [–ATR]	
High	i	u	e$_2$	o$_2$
Mid	e$_1$	o$_1$	ɛ$_2$	ɔ
Low	ɛ$_1$		a	

The underlying ten-vowel system is reflected in a robust ATR vowel harmony process which extends over the whole word. It appears both in height-sensitive syllabification processes and in allomorphy alternations that differentiate between [+ATR] and [–ATR] vowels. [e$_2$] and [o$_2$] consistently pattern with the [–ATR] vowels in selecting the [–ATR] form of affixes, as well as of preverbal subject and object pronouns, and [e$_1$] and [o$_1$] consistently pattern with the other [+ATR] vowels in selecting the corresponding [+ATR] forms. [e$_2$] and [o$_2$] consistently pattern with the high vowels [i] and [u] in undergoing glide formation when immediately followed by another vowel, unlike [e$_1$] and [o$_1$], which are deleted in this context, like other non-high vowels. (37) illustrates how /e$_2$/ patterns as a high vowel in becoming a glide before a vowel ((37a)), while /e$_1$/ patterns as a non-high vowel in deleting before a vowel ((37b)). /o$_2$/ and /o$_1$/ differ analogously.

(37) a. [–ATR]: /sì-úɾùhɾ´ɛ$_1$/ [sjúɾùhɾɛ́] 'pull a rope', /rè$_2$-ɔ̀nɛ́$_2$/ [rjɔ̀nɛ́] 'eat yam'

b. [+ATR]: /sè$_1$-ɔ̀ʃàɾè$_2$ [sɔ́ʃàɾè] 'call a man', /ʊìɛ̀$_1$-ɔ́mɔ́ [ʊjɔ́mɔ́] 'give birth to a child'

In (38) the 1SG pronoun alternates between [+ATR] *mi* and [–ATR] *me$_2$*, and the future auxiliary alternates between [+ATR] *cè$_1$* and [–ATR] *cà*.

(38) a. [–ATR]: mí cé$_1$ sí 'I will write', mí ʒí cè$_1$ có$_1$ 'I will still/also steal'

b. [+ATR]: mé$_2$ cà ɾé$_2$ 'I will eat', mé$_2$ cà kɔ̃́ 'I will plant'

(37) and (38) reveal that the merged vowels remain phonologically differentiated not only within words, but also in small phrases – a rare case where context-freely neutralized contrasts are phonologically active past the word level. If Stratal OT is right in claiming that each level is a parallel constraint system, we must assume either a level of phrasal phonology intermediate between the word and postlexical levels at which the ten-vowel system and harmony continue to operate, with absolute neutralization in the postlexical phonology, or a postlexical ten-vowel system with absolute neutralization by phonetic implementation.

[7] Okpe also underwent the two high/mid mergers, which gave it a nine-vowel underlying system with seven output vowels.

18.4 Yowlumne rounding harmony: phonology and morphology

Every one of the analytic assumptions reviewed above contributes to an understanding of Yowlumne Yokuts phonology.

Yokuts (Yok-Utian) has four underlying vowels with contrastive length, which is mapped via an asymmetric five-vowel system into a symmetrical five-vowel system of surface vowels.

(39)

i iː		u uː		i	u	i iː	u uː
		o oː	→	eː	o oː	e eː	o oː
	a aː		→	a aː		a aː	
stem level				word level		postlexical	

The core phonological processes behind (39) are:

(40) a. Rounding harmony (RH): Left to right between vowels of the same height.
b. Lowering: Long high vowels are lowered and merge with mid vowels.
c. Shortening: Long vowels are shortened in closed syllables.

(41) illustrates their operation.[8]

(41)				
a.	/c̓uːm-hin/	[c̓omhun]	‘devour’ (AOR)	N122
b.	/doːs-hin/	[doshin]	‘report’ (AOR)	K&K90
c.	/c̓uːm-al/	[c̓oːmal]	‘devour’ (DUB)	K&K90
d.	/huluːṣ-taw/	[huloṣtaw]	‘sitting down’ (NONDIR.GER)	N139
e.	/ʔoːy-taw/	[ʔoytow]	‘moving’ (NONDIR.GER)	N139
f.	/yoloːwn-iːn/	[yolownen]	‘will arrive’	N128
g.	/c̓uːm-iːn/	[c̓oːmon]	‘will devour’	N128
h.	/sut̓u-iːn/	[sut̓on]	‘will boil’	N240
i.	/hidiːs/	[hides]	‘wood’	N241
j.	/hidiːs-k̓a/	[hidesk̓a]	‘gather wood’ (IMP)	N241
k.	/miːk̓-hin/	[mek̓hin]	‘swallow’ (AOR)	N42
l.	/c̓uːm-it/	[c̓oːmut]	‘was devoured’ (AOR.PASS)	N125
m.	/huduːk̓-it/	[hudoːk̓ut]	‘were straightened’ (AOR.PASS)	N126
n.	/taxaː-it/	[taxat]	‘was brought’ (AOR.PASS)	N125
o.	/moyoʔn-iː-nit/	[moyoʔneːnit]	‘will be made tired’	N93

The data in (41) illustrate that lowering is always based on underlying length, never on output length, and RH is always based on underlying height, never on output height. Lowering does not bleed rounding in *c̓omhun* and *yolownen*, or feed Rounding in *c̓oːmal* and *moyoʔneːnit*, and Shortening does not bleed Lowering in *c̓omhun*.

(42)				
Underlying	/c̓uːm-hin/	/c̓uːm-al/	/yoloːwn-iːn/	/moyoʔn-iː-nit/
Rounding	c̓uːmhun	— —	— —	— —
Lowering	c̓oːmhun	c̓oːmal	yoloːwneːn	moyoʔn-eː-nit
Shortening	c̓omhun	— —	yolownen	— —
Output	[c̓omhun]	[c̓oːmal]	[yolownen]	[moyoʔneːnit]

Such opacity is problematic for classic OT. Under its core principle of parallel constraint evaluation, non-feeding appears as gratuitous markedness constraint violation, and non-bleeding appears as gratuitous faithfulness constraint violation. All three processes are OPAQUE, partly because they do not interact, and partly because of morphological factors. Yet they are essentially exceptionless, and apply across the board to the entire vocabulary (Newman 1944). The various manifestations of the /uː/ vs. /oː/ distinction are mutually absolutely consistent.

[8] References marked N and K&K here and throughout are to page numbers in Newman (1944) and Kenstowicz & Kisseberth (1979), respectively.

Such data challenge theories that have no rules, and therefore no ordering. Stratal OT meets this challenge by deriving opacity from inter-level seriality: RH applies in the stem phonology, Lowering in the word phonology, and Shortening in the postlexical phonology.

From the OT perspective, a process "applies" when the markedness constraints that drive it outrank the antagonistic faithfulness constraints. In the Stratal OT analysis, markedness constraints that drive rounding harmony dominate the faithfulness constraint IDENT(round) in the stem phonology, and only there. At the word level and postlexically, IDENT(round) is undominated, which precludes any respecification of [Round] in those domains. Similarly, closed syllable shortening applies when the constraint $[*\mu\mu\mu]_\sigma$, which forbids three-mora (superheavy) syllables, dominates the faithfulness constraint IDENT-μ.[9] This ranking must obtain just in the postlexical phonology.

(43) a. Stem phonology: Rounding Harmony (RH > IDENT(Round))

b. Word phonology: Lowering (IDENT(Round) and $*\begin{bmatrix}+\text{High}\\ \text{VV}\end{bmatrix}$ become undominated)

c. Postlexical phonology: Shortening ($*\mu\mu\mu$ becomes undominated)

18.4.1 Predictions

The Stratal OT analysis makes predictions about other phonology/phonology interactions, morphology/phonology interactions, and constraint domains in Yowlumne. A prediction of the first type is that, because shortening is postlexical, it is not masked (counterfed or counterbled) by any other phonological processes. Another is that, because RH is a stem-level process, it does not mask (counterfeed or counterbleed) any other phonological processes. Predictions of the second type are that shortening applies across word boundaries, and that RH is restricted to the stem domain, and does not apply to words or to sentences. The Yokuts data are consistent with all four predictions just stated, and crucially confirm two of them. I begin with closed syllable shortening, and then turn to the more complex case of rounding harmony.

From the way closed syllable shortening relates to lowering and rounding harmony, we inferred that it is postlexical, and should not be masked by any stem-level or word-level process, nor, because of intralevel parallelism, by any other postlexical process. This is confirmed by all other constraints that intersect with closed syllable shortening in the relevant way (K&K p. 85 ff). Yokuts does not permit tautosyllabic consonant clusters in the output, and breaks them up with an epenthetic *i* (which harmonizes to *u*). Short vowels are deleted, provided no tautosyllabic clusters arise thereby. Epenthesis and deletion respectively bleed and feed closed syllable shortening.

(44)	a.	/moːyn-al/	[moynol]	'might become tired'	K&K88
	b.	/moːyn-mi/	[moːyinmi]	'having become tired'	K&K88
	c.	/hud-mi/	[hudmu]	'having known'	N29
	d.	/c̓uyuː-mi/	[c̓uyom]	'having urinated'	N29
	e.	/yoloːw-k̓a/	[yolowk̓o]	'assemble!'	N118
	f.	/ʔiliː-k̓a/	[ʔilek̓]	'fan!'	N118

In (44b) [moːyinmi], epenthesis opens the syllable and prevents (bleeds) shortening. In (44d) [c̓uyom] and (44f) [ʔilek̓], apocope closes the syllable and causes (feeds) shortening.

Yokuts does not tolerate onsetless syllables. *ONSET violations arising from abutting vowels are repaired by deleting the second vowel. (45) shows that the deletion feeds closed syllable shortening.

(45)	a.	/niniː-al/	[ninel]	'(he) may get quiet'	N29
	b.	/c̓uyuː-al/	[c̓uyol]	'(he) may urinate'	N29
	c.	/taxaː-it/	[taxat]	'was brought' (AOR.PASS)	N125

The inventory (39) lacks /e/, /eː/ because *[–Back, –High] is undominated at the stem level. IDENT(low) ranks high, so mid vowels are raised and low vowels converge on [a]. The subsystem of unrounded vowels is accordingly (46).

[9] I adopt $[*\mu\mu\mu]\sigma$ here for the sake of compatibility with other treatments of Yowlumne (van der Leeuw & van de Weijer 1997; Kager 1999: 268; McCarthy 1999), but other approaches to trimoraic syllables would serve as well, including Bye (2007) (they have an extra free mora after them) and Kiparsky (2003) (they are sesquisyllabic feet, with the third mora adjoined at the foot level).

(46)

Stem Level		$*\begin{bmatrix}-\text{Back}\\-\text{High}\end{bmatrix}$	IDENT(low)
/i/, /e/	☞ i		
	e	*	
	æ	*	*
	a		*

Stem Level		$*\begin{bmatrix}-\text{Back}\\-\text{High}\end{bmatrix}$	IDENT(low)
/æ/, /a/	i		*
	e	*	*
	æ	*	
	☞ a		

In the rounded vowels, however, /u/ and /o/ remain contrastive (/ɔ/ is excluded by a separate constraint *[+Rd, +Low], not shown here). At the stem level, IDENT(high) $\gg *\begin{bmatrix}+\text{Hi}\\ \text{VV}\end{bmatrix}$, so long and short vowels behave alike. Only the initial vowel of a harmony domain is distinctively rounded — a vowel in a suffix is always unrounded unless the preceding vowel is rounded and has the same value for [High], in which case it is always rounded. Words like *[dil-mu], *[xat-mu], *[hudal-mu], or *[dub-mi] do not occur. This distribution of rounding follows from the constraint system.

(47)

a. RH: IDENT-σ_1(Round): A segment in an initial syllable must have the same value for [Round] as its I/O correspondent (= (1a.ii)).

b. $*\begin{bmatrix}+\text{Round}\\ \alpha\text{High}\end{bmatrix}\begin{bmatrix}-\text{Round}\\ \alpha\text{High}\end{bmatrix}$ (= (1b)).

c. *[+Round]: A vowel is not [+Round].

d. IDENT(Round): Corresponding input and output segments must have the same value for [Round].

(48)

Stem Level		ID-σ_1 (Rd)	$*\begin{bmatrix}+\text{Rd}\\ \alpha\text{High}\end{bmatrix}\begin{bmatrix}-\text{Rd}\\ \alpha\text{High}\end{bmatrix}$	*[+Rd]	IDENT(Rd)
/u...i/	u...i		*	*	
	☞ u...u			**	*
	i...i	*			*
/o...i/	☞ o...i			*	
	o...u			**	*
	a...i	*			*
/o...u/	o...u			**	
	☞ o...i			*	*
	a...u	*		*	*
/o...a/	o...a		*	*	
	☞ o...o			**	*
	a...a	*		*	*
/i...u/	i...u			*	
	☞ i...i				*
	u...u	*		**	*
/u...a...u/	☞ u...a...i			*	*
	u...a...u			**	

The reason lowering makes RH opaque, then, is that RH applies to stems, while lowering applies to words. Formally, the ranking is harmony ≫ IDENT(Round) in the stem phonology and IDENT(Round) ≫ harmony in the word phonology. In the derivations of [čomhun] and [čoːmal] from the respective inputs /čuːm-hin/ and /čuːm-al/, rounding harmony applies at the stem level:

(49)

Stem level	Id-μ	Id(High)	Id-σ_1 (Rd)	$*\begin{bmatrix}+\text{Rd}\\ \alpha\text{Hi}\end{bmatrix}\begin{bmatrix}-\text{Rd}\\ \alpha\text{Hi}\end{bmatrix}$	*[+Rd]	Id(Rd)
Input: /ċuːm-hin/						
1a. ċoːmhun		*			**	*
1b. ċoːmhin		*			*	
1c. ☞ ċuːmhun					**	*
1d. ċuːmhin				*	*	
1e. ċumhun	*				**	*
1f. ċiːmhin			*			*
Input: /ċuːm-al/						
2a. ċoːmal		*		*	*	
2b. ċoːmol		*			**	*
2c. ☞ ċuːmal					*	
2d. ċuːmol					**	*
2e. ċiːmal			*			

The stem level feeds the word level, where rounding is locked in by the high ranking of Ident(round):

(50)

Word level	+Hi,VV	Ident-μ	Id(Round)	$*\begin{bmatrix}+\text{Rd}\\ \alpha\text{Hi}\end{bmatrix}\begin{bmatrix}-\text{Rd}\\ \alpha\text{Hi}\end{bmatrix}$	*[+Round]
Input: /ċuːm-hun/ (from stem level)					
1a. ☞ ċoːmhun					**
1b. ċuːmhun	*				**
1c. ċoːmhin			*		*
1d. ċuːmhin	*		*	*	*
1e. ċumhun		*			**
Input: /ċuːm-al/ (from stem level)					
2a. ☞ ċoːmal				*	*
2b. ċuːmal	*				*
2c. ċoːmol			*		**
2d. ċuːmol	*		*		**

In the word phonology /iː/ and /uː/ are lowered to [eː] and [oː]. There is still no short */e/. Formally, lowering amounts to promotion of $*\begin{bmatrix}+\text{Hi}\\ \text{VV}\end{bmatrix}$. (51) shows the word phonology, where /iː/, /eː/ and /i/, /e/ are displayed separately to show how length determines height. At this point slashes denote the inputs to the word level.

(51)

Word Level		$*\begin{bmatrix}+\text{Hi}\\ \text{VV}\end{bmatrix}$	Ident(Low)	$*\begin{bmatrix}-\text{Back}\\ -\text{High}\end{bmatrix}$	Ident(High)
/iː/	iː	*			
☞	eː			*	*
	æː		*	*	*
	aː		*		*
/eː/	iː	*			*
☞	eː			*	
	æː		*	*	
	aː		*		
/i/ ☞	i				
	e			*	*
	æ		*	*	*
	a		*		*
/e/ ☞	i				*
	e			*	
	æ		*	*	
	a		*		
/æ, a	i		*		*
	e		*	*	
	æ			*	
☞	a				

Postlexically $[*\mu\mu\mu]_\sigma$ is promoted to effect closed syllable shortening.

(52)

Postlexical	$[*\mu\mu\mu]$	...	Ident-μ	Ident(High)	Ident(Round)
Input: /čoːmhun/ (from word level)					
1a. ☞ čomhun			*		
1b. čumhun			*	*	
1c. čoːmhin	*			*	
1d. čomhin			*		*
1e. čuːmhun	*			*	
1f. čoːmhun	*				

So far we have motivated the following constraint rankings:

(53) a. Stem phonology: RH, $*\begin{bmatrix}-\text{Back}\\ -\text{High}\end{bmatrix}$ $\gg$ Ident(High) $\gg$ $*\begin{bmatrix}+\text{High}\\ \text{VV}\end{bmatrix}$; Ident(Round), Id-$\sigma_1$(Round) $\gg$ *[+Round]; Ident-μ $\gg$ $[*\mu\mu\mu]_\sigma$.

b. Word phonology: Ident(round) and $*\begin{bmatrix}+\text{Hi}\\ \text{VV}\end{bmatrix}$ become undominated.

c. Postlexical phonology: $[*\mu\mu\mu]_\sigma$ becomes undominated.

The levels differ only in the ranking of a markedness constraint with respect to the antagonistic faithfulness constraints.

18.4.2 Absolute neutralization

The underlying vowels are /i, a, u, o/, with distinctive length. In the output vowel system, underlying /uː/ and /oː/ merge into [oː] (which shortens to [o] in closed syllables by $[*\mu\mu\mu]$). The abstract phonological distinction between /uː/ and /oː/ is one of the most convincing instances of absolute neutralization, that is, of the context-free merger of a lexical contrast. The arguments (from Kisseberth 1969 and K&K) are as follows.

First, when [oː] and [o] are derived from /uː/, they harmonize only with high vowels, and when they are derived from /oː/ they harmonize only with nonhigh vowels – recall (41). Secondly, the basic CVCVːC- stem shape with a fixed vocalic melody over the two syllables occurs in the four forms *CoCoːC-*, *CaCaːC-*, *CiCeːC-*, and *CuCoːC-*, derived by spreading the four underlying vowels over an iambic skeleton, with lowering of the long high vowels in /CiCiːC-/ and /CuCuːC-/. Third, word-finally before a glottal stop, /uː/ and /oː/ do *not* merge into [o] (as they normally do under closed syllable shortening), but remain distinct: /ċuyuː-ʔ/ → [ċuyuʔ], but /hoyoː-ʔ/ → [hoyoʔ]. In this special context, then, vowels are shortened *before* they lower (see below). Finally, morphological length alternations treat the two [oː]s differently. [oː] from /oː/ alternates with [o], and [oː] from /uː/ alternates with [u]. All these diagnostics are mutually perfectly consistent. No stem or affix has a vowel that displays a mixture of /uː/ and /oː/ properties.

The lowering of /uː/ to [oː] is paralleled in the front vowels by a lowering of /iː/ to /eː/, but this lowering does not merge two distinct underlying segments into one, for there is no underlying /eː/ in the language. The diagnostics just reviewed reveal no underlying /eː/. Surface [eː] appears *only* where it must be or can be derived from /iː/ by lowering, and surface [e] appears only where it must be or can be derived, almost always from /iː/ by lowering and shortening, as in (41f) [-en] or in (55) [wiyen] (Kuroda 1967: 11; Archangeli & Suzuki 1997: 205).[10] If these vowels were present in the underlying inventory, they would surface also elsewhere. In sum, /e/ and /eː/ are not phonemes of Yokuts.

By OT's fundamental assumptions of Richness of the Base and Freedom of Analysis /eː/ and /e/ surface as [aː] and [a] while /iː/ surfaces as [eː] (and as [e], when shortened in closed syllables), with a scalar faithfulness constraint preventing vowels from lowering all the way to [aː] and [a] (Kirchner 1996; Gnanadesikan 1997; McCarthy 1999). Stratal OT has the added advantage of capturing the distinction between the non-neutralizing lowering of /iː/ to [eː] and the neutralizing lowering of /uː/ to [oː]. The architecture formally predicts that [a] derived from /a/ and [a] derived from /e/ are indistinguishable in Yokuts for purposes of rounding harmony, or any other process for that matter. Because constraint interaction is transparent at each level, a (morpho)phonemic distinction cannot be visible at the level at which it is suppressed, nor, a fortiori, at any later level. Given that /e/ and /eː/ are not visible at the stem level, the distinction between them cannot play any role in the system. In other words, the stem phonology constrains both the underlying segment inventory and the combinatorial constraints on underlying forms ("morpheme structure"), just as it does in Lexical Phonology's solution to the "duplication problem" (Kiparsky 1982). Ruling out /e/ and /eː/ on the stem level accounts for the gap in the vowel inventory. While *no* stem-level constraints treat /iː/ and /eː/ as distinct, *all* stem-level constraints treat /uː/ and /oː/ as distinct. Stratal OT makes a fundamental distinction between these two situations, because it makes contrast relative to a level of representation.

(42) has two stacked opaque relations: lowering counterbleeds and counterfeeds rounding harmony, and shortening, in turn, counterbleeds lowering. This is actually the maximum possible, since there can be at most a word-level overlay on the stem level and a postlexical overlay on the word level. Rule ordering theories allow opaque orderings to be stacked indefinitely. But while empirical studies have demonstrated *transparent* ordering of considerable depth, they have turned up few instances of *opaque* ordering exceeding a depth of two. Tellingly, fast speech phenomena are known to require feeding and bleeding of considerable depth, but no multiply stacked counterfeeding or counterbleeding.

18.4.3 The morphological domain of rounding harmony

Opaque phonology/phonology interactions show that the domain of rounding harmony is the stem. In this section we show that this is independently confirmed by morphology.

Some endings are invariant with respect to rounding harmony: /-xoː-/ (durative), /-iːxoː-/ (consequent, 'be'), /-xoʔ/ (consequent) (N103–108), and /-wiyi-/ 'do', (N55–61).

(54)	a.	/sapaːp-xoː-ʔ/	[sapapxoʔ]	'it is cocked'	N108
	b.	/husuṣ-wiyi-/	[husuṣwiyi]	'stiffen out'	N60

Their vowels must be specified in the input as respectively rounded and unrounded. Newman (1944: 28, 35, 104) offers a perceptive analysis: the invariant suffixes belong to a separate phonological domain, as can be independently inferred from their phonological and morphological behavior.

[10]There is one other source, height assimilation across a glottal stop or /h/, as in /liʔiːʔiċ/ [leʔeːʔiċ] 'one who is sinking', like /muhuːʔiċ/ [mohoːʔiċ] 'one who is sinking' (N17).

The first piece of evidence that the invariant endings belong to a separate phonological domain is their unique stress pattern. According to Newman (35), "these words behave accentually as though a crucial division occurred between the stem and the suffix". The regular word stress of Yokuts falls on the penult syllable.

(55)	a.	/wiyiːn/	[wíyen]	'will tell'
	b.	/panwix-it/	[panwíxit]	'was brought'
	c.	/k̓ulul-wiyi-aːlaːihniː-ʔ/	[k̓ululwiyaːlíhniʔ]	'one who is causing (it) to roll'

But words in /-xoː-/ with a light penult keep the stress of the stem, and end up stressed on the antepenultimate syllable:

(56)	a.	/hoːyiː-xoː-t/	[hóːyexot]	'(it) was being sent'	N35
	b.	/walxuː-xoː-ʔ/	[wálxoxoʔ]	'is passing'	N35, N136
	c.	/tanaː-xoː-ʔ/	[tánaxoʔ]	'takes'	N240
	d.	/puluːm-naː-xoː-ʔ/	[pulómnaxoʔ]	'is getting a husband'	N226
	e.	/hiːç̣ç̣aː-xoː-k̓a/	[héç̣ç̣axok̓]	'be teasing him!'	N104
	f.	/hoːyiː-iːxoː-t/	[hoːyéːxot]	'has been sent'	N108

Evidently the base receives regular penult stress before *-xoː-* is added and retains it as antepenult stress in the finished word. This cyclic transfer of stress is overlain by a *Lapse effect: if the original stress ends up three or more syllables away from the end of the word, a new binary foot is built at the right edge of the word, on which the main stress falls.

(57)	a.	/hoːyiː-xoː-hin/	[hoːyexóːhin]	'(he) was sending (it)'	N35
	c.	/walxuː-xoː-nit/	[walxoxóːnit]	'(he) is being passed'	N36
	d.	/maːwuː-xoː-hin/	[maːwoxóːhin]	'(he) was playing the harp'	N104
	e.	/hul̓uṣ-iːxoː-k̓a/	[hul̓ṣéːxok̓]	'remain seated'	N36
	f.	/ṭ̓uːyuː-iːxoː-hin/	[ṭ̓oːyeːxóːhin]	'was pregnant'	N108

A second clue that the invariant endings belong to a separate phonological domain is that unlike all other-CV(C) suffixes of the language they do not lengthen the final vowel of their bases, e.g., (56c) [tánaxoʔ] vs. [tanáːhin] 'take' (aorist) (N246). Their base appears in what Newman calls the "prefinal stem" form, with a short vowel:

(58)	a.	/hoːyiː-xoː-hin/	[hoːyexóːhin]	'(he) was sending (it)'	N35
	b.	/puluːm-naː-xoː-ʔ/	[pulómnaxoʔ]	'is getting a husband'	N226

Newman terms the invariant endings /-xoː-/, /-xoʔ/, and /-iːxoː-/ "auxiliary clitics", and posits procliticization to /-wiyi-/. However, /-xoː-/ and its cognates are attached to bound stems, not to words as clitics are. And the first elements of /-wiyi-/ verbs are clearly morphological stems, albeit with many special properties.[11] Secondly, all the endings in question are followed by inflectional affixes, which are otherwise affixed to stems. Rejecting the clitic analysis on these grounds, I propose that the invariant morphemes are light verb stems which are compounded with another stem into a word. /-xoː-/, /-xoʔ/, /-iːxoː-/ are allomorphs of the light verb /xoː/ 'be, exist, remain, dwell' (as in the form [xoːxoːhin] just cited), and /-wiyi-/ is an allomorph of the light verb /wiyi/ 'do, say'. Apart from its morphological motivation, the stem-compound analysis is phonologically supported by the fact that /-wiyi-/ blocks the leftward spread of a "floating glottal stop". Floating glottal stops are associated with certain affixes and regularly dock on the second consonant of the stem, if it is a sonorant. But if such an affix is attached to /-wiyi-/, its floating glottal stop docks on the second consonant of /-wiyi-/ itself, e.g., /ṣ̓odod-wiy̓i-iːxoː-ʔ/ [ṣ̓ododwiy̓eːxoʔ] 'is circular' (N107), which indicates that /-wiyi-/ is a stem of its own.

I assume that a syllabic trochee is laid down at the right edge of a stem (Foot-Bin $\gg$ Parse-σ). A binarity requirement bars monosyllabic stems from being stressed. Affixed stems are accentually reparsed (Foot-Bin $\gg$ Ident(stress)). Word-level stress is reassigned only when *Lapse compels it (*Lapse $\gg$ Ident(stress), Foot-Bin, Parse-σ in the word phonology), and the peak is placed

[11] Most stems of /-wiyi-/ verbs are expressive (phonesthemes or ideophones), many are bound. Some can be inflected in their own right and take other derivational affixes. The bound ones have the unique phonological property that they are not subject to closed syllable shortening and lowering of long high vowels (see below).

on the last foot. The generalization is thus that a word is stressed on the stressed syllable of its rightmost stem.

With respect to stress, /-xoː/ and company are neither irregular, nor extrametrical (*pace* Archangeli 1984, 1985). Yowlumne stress in derived words is actually entirely regular and no lexical marking of suffixes or morphological conditioning of stress is required.[12]

The analysis is illustrated here with the derivations of [hoːyexóːhin], [hóːyexot], and [hul̓ṣéːxok̓] (α = Stem, ω = Word).

(59)	Stems:	[hóːyiː]$_\alpha$, [xóː-hin]$_\alpha$	[hóːyiː]$_\alpha$, [xoː-t]$_\alpha$	[húl̓uṣ]$_\alpha$, [íːxoː-k̓]$_\alpha$
	Words:	[[hoːyeː]$_\alpha$ [xóːhin]$_\alpha$]$_\omega$	[[hóːyeː]$_\alpha$ [xoːt]$_\alpha$]$_\omega$	[[hul̓ṣ]$_\alpha$ [éːxoːk̓]$_\alpha$]$_\omega$
	P.L.:	[[hoːye]$_\alpha$ [xóː-hin]$_\alpha$]$_\omega$	[[hóːye]$_\alpha$ [xot]$_\alpha$]$_\omega$	[[hul̓ṣ]$_\alpha$ [éːxok̓]$_\alpha$]$_\omega$

The distribution of final length is apparently a Weight-to-Stress effect. The generalization seems to be that vowels at the right edge of a prosodic domain are short if unstressed and long if stressed. The unique exception to the generalization that a vowel before /-xoː-/ is short is /xoː-xoː-hin/ [xoːxóːhin] 'was living' (N240). /xoː-/ 'be, exist, remain, dwell' (related to the ending /-xoː-/, *ibid.*) is the only monosyllabic verb stem of the language. Presumably a prosodic minimality requirement blocks the otherwise mandatory shortening of the vowel in this case.

In sum, stress and shortening diagnose words with invariant /-xoː-/, /iːxoː/, /-xoʔ/, and /-wiyi-/ as stem-level compounds. The invariant rounding of these elements then follows from the stem-level nature of rounding harmony, according to the previously established rankings.

In this way the morphology and phonology of invariant endings confirms that the domain of rounding harmony is the stem, as we already concluded on the basis of its opaque phonology/phonology interactions. /-xoː-/ and /-wiyi-/ are not exceptions to rounding harmony; in fact, rounding harmony has no exceptions. Rounding is contrastive only in stem-initial syllables. Elsewhere, it may be freely specified in underlying representations, or remain unspecified.

The Stratal OT analysis brings out a fundamental connection between opacity and cyclicity. The effects of a markedness constraint are cyclically inherited from bases to their derivatives at a given level just in case they are represented at that level and protected by a faithfulness constraint. So both opacity and cyclicity reveal the ranking of faithfulness constraints at that level. Opaque rounding harmony in forms like [c̓oːmal] and apparently exceptional rounding in forms like like [sapapxoʔ] (a compound of /sapaːp/ with /-xoː-ʔ/ according to my proposal), are both enabled by the ranking of IDENT(round) at the word level (see (50)).

Conversely, that closed syllable shortening is exclusively postlexical predicts that it is *not* inherited from bases to derivatives in words and stems. The Yokuts data confirm this:

(60) /k̓iliːy/ [k̓iley] 'cloud' (Nom.), /k̓iliːy-in/ [k̓ileːyin] (*[k̓ileyin]) (Gen.) (K30)

The other instance of paradigmatic transfer in Yowlumne stem compounds with /-xoː-/ and related light verbs involves stress. Given our analysis, stress should also be determined at the stem level, and protected by IDENT(stress) at the word level. Two independent facts confirm this: the stem minimality effects just noted, and the Weight-to-Stress effect on stem-final vowels. But there is a subtle difference between stress and rounding. While the ranking of RH is well entrenched, the ranking of word-level IDENT(stress) is fixed only by the facts of word stress. There are no independent data from morphology or opaque constraint interactions to anchor it. So there *could* be a dialect of Yokuts which has the same stress system as Yowlumne except that it does *not* show cyclic transfer of stress in the corresponding forms. Indeed, the Chawchila dialect seems to be of this type:

(61)	a.	Yowlumne:	/tanaː-xoː-ʔ/	[tánaxoʔ]	'takes'	(N241)
	a.	Chawchila:	/panaː-xoː-ʔ/	[panáːxoʔ]	'is arriving'	(N104)

The Chawchila dialect, then, ranks IDENT(stress) below the stress constraints at the word level. No such dialectal variation is expected for rounding and shortening since the relevant rankings are learnable by a rich array of phonological and morphological evidence. Indeed, *all* dialects of Yokuts have transfer of rounding in compounds (N104). And *no* dialect of Yokuts has transfer of shortening in cases like (60). The scope of variation among Yokuts dialects thus confirms that,

[12] As in the case of rounding harmony, there are a handful of *stem-internal* exceptions, see Kuroda (1967), *passim.*

unsurprisingly, rankings are stable in proportion to the amount of evidence for them that is available to the learner. The more interesting inference is that learners are drawing on evidence about opacity to determine the domain of paradigmatic transfer. This speaks in favor of Stratal OT, which makes a connection between opacity and paradigmatic transfer effects, whereas transderivational OT treats them separately.

Another prediction of Stratal OT is that if a phonological property is lexically distinctive in a certain context, it is cyclically preserved in that context (Bermúdez-Otero 2011). This correlation follows because a phonological property is cyclically inherited in a certain environment just in case it is protected by a MAX or IDENT constraint which outranks the markedness constraints that would neutralize it. But exactly that ranking allows an input distinction to surface unscathed.

Although underlying /iː/ and /uː/ are lowered to [eː] and [oː], a postlexical contraction process introduces a set of new long high vowels [iː uː] to take their place.[13] With this, and the shortening of long vowels in closed syllables, Yowlumne ends up with the common five-vowel system /i e a o u/, each occurring both long and short (Newman 1944: 19):

(62)

i iː		u uː
e eː		o oː
	a aː	

The main source of Yowlumne secondary /iː/ and /uː/ vowels is contraction of /-iw-/ to [iː] (and to [uː], in rounding harmony contexts) in the reflexive-reciprocal morpheme /-iws-/ (Newman 1944: 30, 89; Kuroda 1967: 73; Kenstowicz & Kisseberth 1979: 99).

(63)	a. /t̓inik̓-iws-aː-m/	[t̓ink̓iːsam]	‘having hid himself’	N89
	b. /ʔoyoːwix-iws-aː-k̓/	[ʔoyowxiːsak̓]	‘don’t pity yourself’	N89
	c. /c̓udu-c̓udu-iws-aː-xoː-ʔ/	[c̓uduc̓duːsaxoʔ]	‘pull e.o.’s hair (REP)’	N89
	d. /t̓uyu-iws-w/	[t̓uyuːsaw]	‘shoot at each other’	N150

In rule ordering terms, contraction follows lowering, a counterfeeding order. Together with postlexical shortening, it restores the symmetry of the vowel system by supplying the hitherto missing short *e* and reintroducing long /iː/ and /uː/. I assume that is effected by the constraint [-cons]/NUC, which requires nonconsonantal segments (here crucially the [+high] vocoids *i/y, u/w*) to be in the nucleus. [-cons]/NUC is of course dominated by ONSET, inviolable in Yokuts, so its effect is to drive rhymal *y, w* from the coda into the nucleus; they remain onsets where satisfaction of ONSET requires it. Since Yokuts permits no diphthongs, a nucleus *[iw] is impossible and is replaced by [iː].

In the Stratal OT analysis, apart from shortening by [$*\mu\mu\mu]_\sigma$ and contraction, the postlexical vocalism is inherited intact from the word phonology. Thus, [-cons]/NUC and [$*\mu\mu\mu$] are the only constraints considered here which must dominate the faithfulness constraints in the postlexical system.

(64)

Postlexical	[-cons]/NUC	[$*\mu\mu\mu]_\sigma$	IDENT(high)	IDENT-μ
Input: /-iw.sa-/ (from word level)				
1a. -iw.sa-	*			
1b. ☞ -ii.sa-				
1c. -ee.sa-			*	
Input: /-uw.sa-/(from word level)				
2a. -uw.sa-	*			
2b. ☞ -uu.sa-				
2c. -oo.sa-			*	

Tellingly, epenthesis in word-final /-iws/ → [-iwis] bleeds contraction, as we would expect given the postlexical status of contraction that is entailed by the failure of contracted vowels to lower. Note that epenthesis and contraction are potentially mutually bleeding.

A final point concerning the contraction process is that it does not apply to verbal and nominal stems. For example, /huwuṭ-iws-/ → [huwṭuːs-] (prevocalic form), not *[huːṭuːs-] ‘a shell game’ (N30). The reason glides in stems are not affected by contraction is presumably that the templatic

[13] Another source of long [iː] and [uː] in Yowlumne Yokuts are the phonesthemes compounded with [-wiyi-] discussed above.

requirements on the shapes of stems keep them intact. In our example, derived nouns in /-iws-/ invariably have stems of the form /CVCiC/ ∼ /CVCC/, depending on whether a consonant or vowel follows (type IIA stems, in Newman's classification, N187). Contraction of /huwuṭ-/ to *[huːṭ-] would break this pattern. Formally, attributing blocking of contraction in stems to the pattern amounts to ranking the relevant templatic constraints above [-cons]/Nuc.

Thus, although the [*$\mu\mu\mu$] constraint is not masked at a later level, it is not exactly "surface-true", or "automatic" (Newman 1944: 171). It is dominated by a constraint on the shapes of stems and words. This kind of constraint domination is akin to the familiar blocking effect, by which a special rule blocks a general rule in the shared domain, potentially making it non-surface true in that domain.

This points up an interesting difference between Stratal OT and traditional Lexical Phonology. Lexical Phonology simply stipulated that postlexical rules have no exceptions. Instead, Stratal OT *derives* a weaker but more tenable generalization from the fact that postlexical constraints cannot be subverted by later operations. It does *not* exclude constraints from being *dominated* by other constraints in the postlexical phonology, including templatic constraints.

Another instance of templatic constraints blocking phonological processes is that the stems of /-wiyi-/ verbs are not subject to lowering and trimoraic shortening.

(65)	a.	[halaːl-wiyi-]	'arise'	N59
	b.	[baːn-wiyi-]	'run the hand over'	N57
	c.	[hiːt̓-wiyi-]	'inhale smoke'	N57
	d.	[xiːs-wiyi-]	'float downward'	N58
	e.	[yuːx-wiyi-]	'melt'	N58
	f.	[c̣itiːk̓-wiyi-]	'make a short turn'	N59

They can even be lengthened ("rhetorically" as Newman puts it) to express a longer duration of the activity denoted by the verb (N57).

(66) a. [hik̓wiyi] 'make a hiccuping sound', [hiːk̓wiyi] 'make a panting sound'
b. [palwiyi] 'overspread quickly', [paːlwiyi] 'overspread slowly'
c. [puṭ'wiyi] 'whirl about', [puːṭ'wiyi] 'fill the air with whirling motion'

This part of the vocabulary seems to stand outside of the lexical system.[14] Instead of obeying the constraints of lexical phonology, such elements may be subject to templatic constraints of their own.

Otherwise, all morphophonological constraints on the length of stems are subordinated to closed syllable shortening. For example, a class of affixes impose an iambic (CVCVːC-) shape on their stems (the "strong stem", Newman 1944: 49). The strong stem is invariably shortened to CVCVC- when its second syllable is closed before a consonantal suffix. Also, stem-final vowels in Yokuts are obligatorily long at the stem level, and invariably shortened in closed syllables. The corresponding constraints on stems are, therefore, active only in the lexical phonology.

Another instance of opaque rounding harmony arises from the deletion of final stem vowels before vocalic endings (Newman 1944; Kuroda 1967: 20). The deleted vowel optionally triggers rounding harmony (Newman 1944: 115).

(67)	a.	/wastuː-in-k̓a/	[wastunk̓a]	∼	[wastink̓a]	'get hurt' (imp)
	b.	/walxuː-it/	[walxut]	∼	[walxit]	'(he) was passed'
	c.	/baːluː-ihniː-/	[baːluhnoː-]	∼	[baːlihneː-]	'one who is feeling about in the dark'

The forms with unrounded vowels in (67) show the transparent interaction of deletion and harmony expected under OT. In the forms with rounded vowels, the rounding is opaquely conditioned by the deleted vowel. In Newman's words (p. 85), the variation reveals "a conflict between the harmonizing force of the last overt vowel of the stem (e.g., wast-) and the last implicit vowel (e.g., wast[oː]-)". Stratal OT models this conflict by level-ordering. We know that rounding harmony takes effect at the stem level, and only there. When truncation also applies at the stem level, it interacts transparently with RH, bleeding RH (output: [wastink̓a]). When truncation is deferred until the word level, RH is

[14]Special phonology is typical of phonesthemes and interjections. In English and other languages they have exceptional syllable structures (*hmm, shhh, psst*) and even exceptional sounds (such as the click conventionally spelled *tisk* or *tut*), as well as more subtle violations of lexical constraints (e.g., *bam, bang, wham* with untensed [æ] in Philadelphia).

opaque (output: [wastunk̓a]). Since truncation takes effect when MAX-V is outranked by ONSET (as well as by constraints such as DEP-C that bar alternative resolutions of hiatus), the variation in the level at which Truncation applies depends on when the ranking ONSET, DEP-C $\gg$ MAX-V obtains. If it obtains at the stem level, truncation bleeds harmony, if only at the word level, harmony applies opaquely. This is another example of variation at a locus of weakly entrenched ranking.

18.5 Conclusion

Vowel harmony appears to be consistent with off-the-shelf Stratal OT, and requires no problematic constraint types such as ALIGN, AGREE, and SHARE, no harmony-specific mechanisms such as Search-and-Copy and Agreement-by-Correspondence, and no extrinsic rule ordering. Morphology and the asymmetry between marked and unmarked values of the harmonic feature do most of the explanatory work. Harmony systems provide novel evidence for Stratal OT's core assumptions of cyclicity and level-ordering. In particular, we documented a hitherto unnoticed type that it predicts, where roots harmonize with affixes and affixes harmonize with stems. The intrinsic constraints that SOT imposes on abstract representations and rule interaction allow a principled account of even the benchmark system of Yowlumne Yokuts, where a simple and regular harmony process becomes multiply opaque by being embedded in a complex level-ordered phonology.

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