

8 Harmony Systems

SHARON ROSE AND RACHEL WALKER

1 Introduction

This chapter addresses *harmony systems*, a term which encompasses consonant harmony, vowel harmony, and vowel-consonant harmony. Harmony refers to phonological assimilation for harmonic feature(s) that may operate over a string of multiple segments. This can be construed in one of two ways. Two segments may interact “at a distance” across at least one (apparently) unaffected segment, as shown for consonant harmony in (1a). Or, a continuous string of segments may be involved in the assimilation, as shown for vowel-consonant harmony in (1b). The subscripts refer to features or feature sets.

- (1) a. *distance harmony*
consonant harmony $C_x V_y C_z \rightarrow C_z V_y C_z$
b. *continuous harmony*
vowel-consonant harmony $C_x V_y C_z \rightarrow C_z V_z C_z$

Although only three segments are represented in the diagram in (1), harmony can apply to longer strings. As for vowel harmony, it can operate at a distance depending on how one construes intervening consonants and/or vowels that are apparently unaffected by the assimilation. It may also be construed as continuous if intervening segments participate in harmony. Furthermore, vowel-consonant harmony can operate at a distance, skipping over some segments.

In this chapter, we first provide a descriptive overview of the basic patterns of the harmony systems outlined in (1), with a focus on the triggers (segments that cause harmony) and targets (segments that undergo harmony). We also touch on blocking segments (ones that halt harmony) and transparent segments (ones that

appear to be skipped by harmony but do not prevent it from extending past them). We then elucidate the main analytical trends and advances that phonological theory has brought to bear on harmonic systems. First, not all harmony systems show the same characteristics or are amenable to the same type of basic analysis. Specifically, there appears to be a split between consonant harmony on the one hand and vowel harmony and vowel-consonant harmony on the other. Second, there has been a shift from emphasis on tier-based representational solutions for issues such as blocking and harmony drivers in favor of alternative explanations articulated within Optimality Theory, such as phonetically-motivated featural co-occurrence constraints and agreement constraints that are non-specific about targets. Third, an increased appeal to functional explanations has been sought for harmony patterns. Finally, broader typological coverage has led to progress on topics such as directionality and consonant harmony, but has also provided challenges to well-established conceptual issues.

The chapter is organized as follows. In Section 2, we introduce and illustrate the main properties of harmony patterns. In Section 3.1 we discuss autosegmental approaches. In Section 3.2, we show how consonant harmony has come to be analyzed through correspondence-based constraints which require participating similar segments to match. Vowel harmony and vowel-consonant harmony share many issues, addressed in Section 3.3. These include conceptualization of the harmony imperative, or what drives harmony, feature classes, blocking and transparency. In Section 3.4 we discuss the disparate cases of non-local vowel-consonant harmony. In Section 4.1, we address directionality, and in Section 4.2, phonologically and morphologically defined harmony domains are explored. In Section 5 new trends and directions for future research are presented.

2 Harmony Patterns

2.1 Consonant Harmony

We define consonant harmony as assimilation between consonants for a particular articulatory or acoustic property operating at a distance over at least another segment.¹ Consonant harmony can involve both alternations in affixes and morpheme structure constraints (Shaw 1991; Hansson 2001b, 2010; Rose and Walker 2004).

2.1.1 Coronal Harmony The most commonly attested type of consonant harmony is *sibilant harmony*, which requires sibilant coronal fricatives and affricates to match for tongue tip/blade posture and location. It is widely attested in Native American languages, but also occurs elsewhere. In Ts'amakko, a Cushitic language of Ethiopia (Savà 2005), the causative suffix *-as* (2a) is realized as [aʃ] when palatoalveolar fricatives or affricates appear in the preceding stem (2b):

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|-----|----|------|-----------|---------|----------------|
| (2) | a. | baɕ | 'to hide' | baɕ-as | 'to make hide' |
| | | ɕabb | 'to take' | ɕabb-as | 'to make take' |

	bas	'to do'	bas-as	'to make sb. do'
	zaq'	'to slaughter'	zaq'-as	'to make sb. slaughter'
b.	ʧ'ur	'to throw'	ʧ'ur-aʃ	'to make sb. throw'
	fukuy	'to be scared'	fukuy-aʃ	'to scare'

Sibilant harmony operates across vowels and non-sibilant consonants, including other coronals. In (2b), the intervening segments do not block and do not participate in the harmony. In roots, in addition to matching for tongue tip-blade posture and location, sibilants must be identical: e.g. *ziiz-a* 'backbone' **ziis-a*. In Ts'amakko, harmony operates from left to right, that is, progressively; the trigger is palatoalveolar and the target an alveolar.

In some languages such as Ineseño Chumash (Applegate 1972; Poser 1982), alveolars may trigger harmony. The rightmost sibilant determines the tongue tip-blade realization of all sibilants in the stem. In (3a), the 3sg. subject prefix is /s-/, but it is realized as [ʃ] if there is a palatal sibilant to its right in the stem (3b). In contrast, the dual marker /if-/ (3c) is realized as [is] if followed by an alveolar sibilant (3d).

(3)	a.	/s-ixut/	[sixut]	'it burns'
	b.	/s-ilakʃ/	[ʃilakʃ]	'it is soft'
	c.	/p-if-al-nan'/	[piʃanan']	'don't you two go'
	d.	/s-if-tifi-yep-us/	[sistisiyepus]	'they two show him'

Dental harmony is found in Nilotic languages. It operates between dental and alveolar stops, including nasals if a contrast exists in the language, and it may be triggered by consonants at either place. In Pãri (Andersen 1988; Hansson 2001b, 2010) dental harmony is respected in roots (4a). Root-final stops that are the product of final mutation combined with affixation match the dental or alveolar property of the initial stop (4b).

(4)	a.	ṅɔ̄t̄	'sucking'		
		àtwá:t̄	'adult male elephant'		
	b.	dè:l	'skin'	dè:nd-á	'my skin'
		ṭùol	'snake'	ṭùoṅṅ-á	'my snake'

Retroflex harmony is reported for Gimira (Benchnon), an Omotic language of Ethiopia (Breeze 1990). In this language, coronal sibilants in roots match in retroflexion (and tongue tip-blade distinctions s/ʃ) and a causative suffix /-s/ agrees for the retroflex feature with a preceding root consonant across intervening vowels and consonants, including non-retroflex /r/. Numbers indicate tone levels.

(5)	a.	mak 2	'say'	mas 2	'cause to say'
		dub 4	'dance'	dus 4	'cause to dance'
	b.	zert 1	'be red'	zerṭ 1	'make red'
		ṭʃ'ud'	'spit'	ṭʃ'uʃ'	'cause to spit'

Retroflex harmony can affect sibilants, as in Gimira, or operate between oral and nasal stops, as in Australian languages such as Arrernte (Arandic) (Henderson 1988; Tabain and Rickard 2007) in which apical alveolar and retroflex stops match for retroflexion in a root. Arsenault and Kochetov (to appear) report that Kalasha roots exhibit retroflex consonant harmony between stops, fricatives, and affricates, respectively, but only when participating consonants have the same manner of articulation. Root-internal combinations of retroflexes and non-retroflexes with the same manner of articulation are rare or unattested. If manner differs, retroflex, and non-retroflex consonants freely combine. In all the reported cases, retroflex harmony appears to be sensitive to manner distinctions.

2.1.2 Nasal Harmony In nasal consonant harmony, nasal stops typically harmonize with voiced stops and oral sonorant consonants. Nasal consonant harmony is attested primarily in Bantu languages. In Yaka (Hyman 1995), a nasal stop in a root causes a /d/ or /l/ in the perfective suffix (6a–c) to become [n] (6d–f). Prenasalized stops are not triggers (6c) and do not block harmony (6f). Vowel height harmony regulates the height quality of the suffix vowel.

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|--------|-----------|------------|----|-----------|--------|
| (6) a. | sól-ele | ‘deforest’ | d. | kém-ene | ‘moan’ |
| b. | jád-idi | ‘spread’ | e. | nútúk-ini | ‘bow’ |
| c. | kú:nd-idi | ‘bury’ | f. | mé:ng-ene | ‘hate’ |

Intervening vowels and non-participating consonants are transparent to the harmony.

2.1.3 Liquid harmony Liquid harmony involves alternations between /r/ and /l/. In Bukusu (Bantu), it is attested in roots (Hansson 2001b, 2010). In addition, the benefactive suffix /-il-/ is realized as [-ir-] following a stem with [r] (Odden 1994a). Vowel height harmony causes the suffix vowel to lower to mid following mid vowels.

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|--------|-----------|-----------------|----|-----------|----------------|
| (7) a. | te:x-el-a | ‘cook for’ | d. | re:b-er-a | ‘ask for’ |
| b. | lim-il-a | ‘cultivate for’ | e. | kar-ir-a | ‘twist’ |
| c. | i:l-il-a | ‘send thing’ | f. | resj-er-a | ‘retrieve for’ |

In Sundanese (Malayo-Polynesian), /l/ triggers harmony of /r/ to [l] (Cohn 1992), as with the plural infix /-ar-/ in (8f).

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|--------|-------|-----------|----|-----------|---------------|
| (8) a. | kusut | ‘messy’ | d. | k-ar-usut | ‘messy’ PL. |
| b. | rahit | ‘wounded’ | e. | r-ar-ahit | ‘wounded’ PL. |
| c. | læga | ‘wide’ | f. | l-al-æga | ‘wide’ |

2.1.4 Dorsal Harmony Dorsal harmony is found in Totonacan languages, and involves alternations between velar and uvular consonants. In Tlachichilco Tepehua (Watters 1988; Hansson 2001b, 2010), a uvular /q/ causes a preceding

velar to become uvular, which in turn conditions lowering of the preceding high vowel (9b).

- (9) a. ʔuks-k'atsa: [ʔuksk'atsa:] 'feel, experience sensation'
 b. ʔuks-laqts'-in [ʔoqlaqt's'in] 'look at Y across surface'

In general, dorsal harmony targets velar consonants, altering them to uvular.

2.1.5 Laryngeal Harmony Laryngeal harmony requires consonants to agree for the laryngeal properties of aspiration, glottalic airstream, or voicing, as characterized by the features [spread glottis], [constricted glottis], and [voice], respectively. It appears frequently in morpheme structure constraints (MacEachern 1997 [1999]), but is rarer in patterns showing alternations.

Voicing and aspiration harmony is found in (non-click) stops in morphemes of Zulu (Bantu), as in (10a) (Khumalo 1987; Hansson 2001b, 2010). Loanwords (10b) also obey the restriction.

- (10) a. ukú-peta 'to dig up'
 úku-p^hát^ha 'to hold'
 uku-guba 'to dig'
 b. í-k^hòt^ho 'court'
 um-bídi 'conductor' < English 'beat'

Kera (Chadic) appears to have voicing alternations in affixes conditioned by voiced stops or affricates in the stem (Ebert 1979; Rose and Walker 2004), e.g. kə-sár-kán 'black (coll.)' vs. gə-ɕàr-gán 'colorful (coll.)'. However, Pearce (2005) has argued that voicing is actually conditioned by a neighboring low tone rather than the voiced stop in the stem. Hansson (2004b) also argues that in Yabem, a Huon Golf language of Papua New Guinea, voicing restrictions arose from tonal patterns rather than from consonant harmony.

Harmony for [constricted glottis] occurs in Chaha, a Semitic language of Ethiopia (Rose and Walker 2004), in which oral stops match for both [constricted glottis] and [voice]:

- (11) a. jì-t'ək'ir 'he hides'
 jì-t'əβk' 'it is tight'
 b. jì-kətf 'he hashes (meat)'
 jì-kəft 'he opens'
 c. jì-gədīr 'he puts to sleep'
 jì-dərg 'hits, fights'

Most exceptions to laryngeal harmony differ in both features (Rose and King 2007), ex. jì-gəmt' 'he chews off, gnaws' or jì-dəfk' 'he scrubs and pounds laundry'.

In addition to the main types reported here, (Hansson 2001b, 2007b) also lists stricture and secondary articulation harmonies. Stricture involves alternations

between stops and fricatives, and is attested in Yabem, e.g. *se-dàgù?* → [tédàgù?] ‘they follow’ REALIS. Secondary articulation refers to labialization, palatalization, velarization or pharyngealization. There are a few reported cases discussed in Hansson (2007b): pharyngealization in Tsilhqot’in (also known as Chilcotin, Athapaskan) (Cook 1976, 1983, 1993), which interacts with sibilant harmony, velarization in Pohnpeian (Micronesian) (Rehg and Sohl 1981; Mester 1988) and palatalization in Karaim (Turkic) (Kowalski 1929; Hamp 1976; Nevins and Vaux 2004a), as shown below:

- (12) a. kⁱum^hujⁱ-sⁱuzⁱ ‘penniless, unpaid’
 b. k^horkuv-suz ‘fearless, safe’

In sum, consonant harmony targets a range of segments: dorsals, liquids, and coronal obstruents, as well as segments classified according to nasal and laryngeal features. A consistent characteristic is that the interacting segments share a high degree of similarity. Notably absent is harmony for major place features such as [labial], [coronal], or [dorsal], as well as classificatory features that tend not to assimilate even locally, such as [sonorant] or [consonantal].²

2.2 Local Vowel-consonant Harmony

Harmony in which contiguous strings of segments are affected is labeled *vowel-consonant harmony*. This type of local harmony involves vowels and consonants and can be triggered by either. Three main types are outlined: nasal harmony, emphasis harmony, and retroflex harmony.

2.2.1 Nasal Harmony Nasal harmony is triggered by nasal consonants or vowels, and affects vowels and certain consonants depending on the language. An example of nasal harmony triggered by vowels is found in Epena Pedee, a Choco language of Colombia (Harms 1985, 1994; Walker 1998[2000]):

- (13) /perōra/ [peṛōṛã] ‘guagua (a groundhog-like animal)’
 /ũbuisi/ [ʔũ^mbuisi] ‘neck’
 /wāhida/ [wāḥĩⁿda] ‘they went’ (go PAST.PL.)
 /wāīt^hee/ [wāi^{nt}ḥee] ‘go’ (future)
 /dāwe/ [nāwē] ‘mother’
 /k^hĩsia/ [k^hĩsiã]³ ‘think’

In this language, nasal harmony is triggered by a nasal vowel and nasality spreads progressively onto vowels, glottals, glides, and liquids, but it is blocked by obstruents and the trill /r/.⁴ Stops at the right edge of the harmonic domain are pre-nasalized. In addition, the onset of the syllable containing a nasal vowel is nasalized; in this position, voiced stops become fully nasal and fricatives are nasalized, but voiceless stops remain oral.

Nasal harmony triggered by nasal consonants is attested in Capanahua, a Panoan language (Loos 1969; Walker 1998 [2000]).

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|------|----------|----------------|------------|---------------------|
| (14) | ĩonāmpān | 'I will learn' | kajatānai? | 'I went and jumped' |
| | pōjān | 'arm' | ʃipōŋki | 'downriver' |
| | bīmuu | 'fruit' | warān | 'squash' |

In Capanahua, nasal stops trigger nasal harmony regressively to vowels, glides, and glottals, but harmony is blocked by obstruents and liquids.

Nasal harmony differs cross-linguistically in terms of which segments undergo nasalization and which block harmony, as documented in Walker (1998 [2000]). Prior foundational surveys on nasalization patterns include Schourup (1972), Piggott (1992), and Cohn (1993b, c) (note also Pulleyblank 1989). Cross-language variation occurs in a nested dependency relationship: vowels > glides > liquids > fricatives > stops. If liquids are nasalized, so will be more sonorous segments such as glides and vowels. If liquids block nasalization, so will less sonorous segments such as fricatives and stops. In the examples above, nasalization targets vowels, glides, and liquids in Epena Pedee, but obstruents block progressive harmony. In Capanahua, nasalization affects vowels and glides, whereas both obstruents and liquids block harmony. In Sundanese (Robins 1957; Cohn 1990), nasalization spreads progressively to vowels and laryngeals (15a), but is blocked by obstruents, liquids, and glides (15b):

- | | | | | | | |
|------|----|---------|-----------|----|---------|-------------|
| (15) | a. | nāĩān | 'to wet' | b. | nājak | 'to sift' |
| | | kumāĩhā | 'how?' | | nūdāg | 'to pursue' |
| | | mĩĩāsīh | 'to love' | | mōlohok | 'to stare' |

In Applecross Scottish Gaelic (Celtic) (Ternes 1973), nasalization spreads from a stressed nasal vowel in the syllable and progressively to vowels, laryngeals, glides, liquids, and fricatives, but is blocked by obstruent stops:

- | | | | |
|------|-------------|--------------|---------------|
| (16) | /mā·har/ | [mā·hāĩ] | 'mother' |
| | /tʰianu/ | [tʰiānũ] | 'to do, make' |
| | /frīa·v/ | [frīā·ṽ] | 'root' PL. |
| | /kʰʷispaxk/ | [kʰʷiĩspaxk] | 'wasp' |

Finally, in many South American languages, particularly of the Tucanoan family, voiceless stops and fricatives are transparent to nasal harmony, neither undergoing nasal harmony nor blocking it, as in Tuyuca (Barnes 1996). In this language, nasality spreads bidirectionally with no blocking, even by voiceless obstruents. Morphemes are oral or nasal; voiced stops are in complementary distribution with nasal stops in the harmonic domain.

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|------|------|-------------|-------|-----------------|
| (17) | wáa | 'to go' | w̃áā | 'to illuminate' |
| | hoó | 'banana' | h̃oó | 'there' |
| | osó | 'bat' | j̃osó | 'bird' |
| | bipí | 'swollen' | m̃ipí | 'badger' |
| | sigé | 'to follow' | t̃ĩŋó | 'Yapara rapids' |

Mòbà Yoruba (Benue-Congo) is also reported to have transparent voiced and voiceless obstruents (Ajíbóyè and Pulleyblank 2008; Piggott 2003; Archangeli and Pulleyblank 2007), e.g. /udũ/ → [ūdũ] ‘lover of sweet things’, /isĩ/ → [ĩsĩ] ‘worship’.

2.2.2 Emphasis Harmony Emphasis harmony is a term for pharyngealization or uvularization harmony, sometimes labeled post-velar harmony (Shahin 2002), and is found in Arabic and Aramaic (Semitic) dialects, as well as Berber (Kossmann and Stroomer 1997). Emphasis in Arabic is normally treated as a process triggered by the emphatic coronal obstruents /tˤ dˤ sˤ ðˤ/ (or /zˤ/ in some dialects), which contrast with plain counterparts: e.g. d̄em ‘blood’ vs. dˤem ‘he hugged’ in Jordanian Arabic (Al-Masri and Jongman 2004). Moreover, other consonants such as liquids and labials may be emphatic, and pharyngeals can trigger emphasis harmony. Al-Ani (1970), Dolgopolsky (1977), Ghazeli (1977), Zawaydeh (1999), and Shahin (2002) provide evidence that emphasis harmony is uvularization, distinguished from pharyngealization. There is articulatory evidence for upper pharyngeal constriction, characteristic of uvulars. The primary acoustic effect of emphasis/uvularization is a large drop in F2 on neighboring vowels, while pharyngealization produces a high F1. Lehn (1963) and Watson (1999, 2002) note that in addition to tongue root retraction and general pharynx contraction, articulatory correlates may include labialization, lateral spreading, and concavity of the tongue. In Yemeni Arabic, labialization causes short high vowels to round in emphasis contexts: e.g. yimalli:hin ‘he fills them F.’ vs. yusˤaffi:hun ‘he cleans them F.’ (underlining indicates emphasis, here and below).

Examples of emphasis spread in Cairene Arabic are given below (Watson 1999: 274). See also Gairdner (1925), Harrell (1957), Lehn (1963), Abdel-Massih (1975) for discussion.

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|------|-----------------|-----------|----------------|-----------------|
| (18) | <u>sˤubya:n</u> | ‘boys’ | <u>rabatˤ</u> | ‘he bound’ |
| | <u>dˤarab</u> | ‘he hit’ | <u>basˤala</u> | ‘onion’ |
| | <u>maradˤ</u> | ‘illness’ | <u>xaddˤar</u> | ‘to make green’ |

Emphasis harmony minimally spreads to an adjacent vowel (Broselow 1976), a type of local assimilation, but maximally it extends across the entire phonological word, affecting both consonants and vowels. An example of word-level harmony in (19) is from Azerbaijani Jewish Aramaic (Hoberman 1988), where spreading is bidirectional. In this language, words are only rarely disharmonic, and affixes alternate in accordance with the harmonic root:

- | | | | | |
|------|-----------|------------------|------------------|---------------|
| (19) | xarupa | ‘sharp’ | <u>xamusa</u> | ‘sour’ |
| | xarip-ula | ‘sharpness’ | <u>xamis-ula</u> | ‘sourness’ |
| | xof | ‘good, pleasant’ | <u>razi</u> | ‘satisfied’ |
| | na-xof | ‘ill, sick’ | <u>na-razi</u> | ‘unsatisfied’ |

When emphasis harmony affects all segments in a word, it is sometimes difficult to identify the trigger, and this has led some researchers to propose that the

emphasis feature is a property of the syllable (Lehn 1963; Hoberman 1988) or a suprasegmental feature of the word (Harrell 1957; Tsereteli 1982) rather than a particular segment.

Emphasis harmony can be blocked by high (front) vowels and consonants. In Cairene Arabic, non-tautosyllabic high front vocoids optionally block harmony to the right of the emphatic consonant (20a); compare with (20b). It is not blocked by a tautosyllabic high front vowel (20c) or in leftward harmony (20d) (Watson 1999, 2002).

- (20) a. s^ha:hib 'my friend M.' b. as^hha:b 'friends M.'
 ʕas^hafi:r 'small birds' as^hfu:r 'small bird'
 c. taxd^hi:r 'making green' d. wis^hil 'he arrived'
 t^hifl 'child' ʔami:s^h 'shirt'

In a southern Palestinian Arabic dialect discussed by Davis (1995a), emphasis harmony spreads bidirectionally. Leftward spreading is unimpeded (21a) but rightward spreading (21b) is blocked by high front segments /i j ɟ/ (21c). Similar effects are found in other dialects (Younes 1991; 1993).

- (21) a. ʔabsa:t^h 'happier'
 nafa:t^h 'energy'
 maɟass^has^hijf 'it did not solidify'
 b. s^haba:h 'morning' c. s^hajja:d 'fisher, hunter'
 ʔat^hfa:l 'children' ʕat^hfa:n 'thirsty'
 t^hu:b-ak 'your M.SG.blocks' t^hi:n-ak 'your M.SG. clay'

Al-Masri and Jongman (2004) report that in Jordanian Arabic, high vowels in words such as /t^hubəh/ 'brick' exhibit lower F2 consistent with emphasis harmony, but this does not extend to the vowel in the next syllable. This contrasts with the pattern in words without high vowels. In Abu Shusha Palestinian Arabic (Shahin 2002), the obstruents /ʃ ɧ ɟ/ block emphasis harmony in both directions: regressive /ʕaʃar^ha/ → ʕaʃar^ha 'ten' or progressive /ʕat^hʃa:n/ → ʕat^hʃa:n 'thirsty' M.SG. but non-low vowels are transparent to harmony: /muhr^h-a:t/ → m^hu^hur^ha:t^h 'fillies'.⁵

2.2.3 Retroflex Harmony Retroflex harmony in Sanskrit (Indo-Aryan) is a system which appears to operate at a distance between consonants. Retroflex continuants (/ʃ/ or /r/) cause a following dental nasal to become retroflex [ɳ], as shown for the nominal and adjectival suffix /-ana/ (Whitney 1889). This harmony applies freely over non-coronals and vowels (22a), but is blocked by other intervening consonantal coronals (22b):

- (22) a. rakṣaṇa 'protection' b. varḍana 'increase'
 krpaṇa 'miserable' rocana 'shining'
 ākramaṇa 'striding' vrjana 'enclosure'
 kṣayaṇa 'habitable' ceṣṭana 'stirring'

Whitney (1889) assumes that the tongue remains in the retroflex position until it encounters another consonant which requires a different position of the front and tip-blade of the tongue. This explains the dental coronals' blocking. This interpretation is adopted by Flemming (1995), Gafos (1996 [1999]), Ní Chiosáin and Padgett (1997), and others. Under this analysis, retroflex harmony constitutes vowel-consonant harmony rather than consonant harmony. To explain the fact that retroflex consonants also block harmony, Gafos (1996 [1999]) argues that only retroflex *continuants* can act as triggers, although Ní Chiosáin and Padgett (1997) argue against this position. Nevertheless, Hansson (2001b, 2010) argues that four typological properties of Sanskrit retroflex harmony set it apart from consonant harmony: opacity, disjoint sets of triggers and targets, directionality, and the domain of harmony (which may be phrasal).

Like Sanskrit, Kinyarwanda (Bantu) has a retroflex harmony that shows blocking. Harmony is regressive and causes an alveolar fricative to become retroflex when it precedes a retroflex fricative in a stem (Walker and Mpiranya 2006; Walker, Byrd, and Mpiranya 2008). Harmony is blocked by alveolar stops and affricates, retroflex stops, and palatal consonants. Intervening vowels and non-coronal consonants do not block harmony and are not perceptibly affected. However, an articulatory study of non-coronal consonants that intervene between harmonizing fricatives reveals that a retroflex posture is actually present during them (Walker *et al.* 2008). This finding is suggestive that the harmony causes a retroflexion feature to be present during the segments that separate audibly harmonizing fricatives, that is, it is a vowel-consonant harmony.⁶

In other patterns, harmony from retroflex consonants can explicitly target vowels across another consonant, as in Mpakwithi (Northern Paman) (Evans 1995), e.g. gwapɪa → [ŋwa^fɪa] 'is eating'.

In sum, there are relatively few vowel-consonant harmony types, being restricted to articulations that are compatible with both vowels and consonants such as nasality, tongue root retraction and retroflexion. Another striking difference between vowel-consonant harmony and consonant harmony is that vowel-consonant harmony exhibits blocking effects, whereas consonant harmony does not. This is a characteristic shared by vowel harmony, as discussed in Section 2.4.

2.3 Non-local Vowel-consonant Harmony

Non-local vowel-consonant harmony is relatively rare, and differs from local harmony. Odden (1980) discusses reported cases of vowels palatalizing or causing velar shifts across a single, unaffected, intervening consonant. Three cases involving greater distances are discussed here.

Faucal or retraction harmony is attested in Salish languages such as Snchitsuʔumshtsn (also known as Coeur d'Alene) and Spokane-Kalispel-Flathead (Bessell 1998). In Snchitsuʔumshtsn there is both local retraction (backing and/or lowering) of vowels adjacent to a faucal consonant (uvular and pharyngeal), as well as non-local retraction. In the following examples, /i/ is retracted to [ɛ] and /ɛ/ to [ɑ].

- | | | | | | |
|------|------------------|------------------------------------|--------------------|--|-----------------|
| (23) | <i>Local</i> | u-tseŋ ^w | 'it's bright red' | | |
| | <i>Non-local</i> | t ^s ɛf-ɑlq ^w | 'he is tall' | cf. t ^s ɪf-t | 'it is long' |
| | | neʔ-sátt ^f -ɛʔqs-n | 'crank (on a car)' | cf. sétt ^f -nt ^s | 'he twisted it' |

Bessell (1998) argues from acoustic evidence that intervening consonants are unaffected by the retraction. Tigre (Semitic) /ə/ is reported lowered to [a] preceding ejectives and pharyngeals across other vowels and consonants (Palmer 1956; Odden 1980), but Rose (1996) found that other vowels were slightly lowered and retracted, suggesting a similar process to that of Sncchitsuʔumshtsn.

Sibe (Tungusic) has progressive rounding vowel harmony and a vowel system that distinguishes two basic heights: /i y i u ɛ ø a ɔ/ (Li 1996). Velar consonants in suffixes are realized as uvular if a non-high vowel appears in the preceding stem. This alternation takes place even across a high vowel.

- | | | | |
|------|-------------------|----------|--------------------------------------|
| (24) | <i>Diminutive</i> | | <i>Non-self perceived past tense</i> |
| | ıldi(n)-kin | 'bright' | tɪ-xi 'to sit' |
| | muxuli(n)-kin | 'round' | içi-xi 'to be enough' |
| | sula-qɪn | 'loose' | tyke-χi 'to watch' |
| | adzi(g)-qɪn | 'small' | fɔndzi-χi 'to ask' |

In Harari (Semitic), the rightmost coronal consonant (except /r/) in the 2F.SG. non-perfective is palatalized by the suffix -i. Palatalization may occur on more than one consonant (25b,e) and affects both roots and prefixes (Rose 2004).

- | | | | |
|------|---------------|------------------------|----------------|
| (25) | 2M.SG. | 2F.SG. | |
| | a. ti-kafti | ti-kaff-i | 'open' |
| | b. ti-bitasi | ti-bitafi / ti-bitɸafi | 'rip' |
| | c. ti-k'admi | ti-k'adɸm-i | 'advance' |
| | d. ti-dinak'i | ti-dinak'-i | 'be surprised' |
| | e. ti-fit'ani | ti-fit'ɸn-i | 'hurry' |
| | f. ti-sabri | ti-fabr-i | 'break' |
| | g. ti-barri | ɸi-barr-i | 'fly' |

These three non-local harmony cases bear some similarities to local interactions. Faucal harmony has its roots in local retraction of vowels, which is also regressive (Bessell 1998). Velars can become uvular adjacent to non-high back vowels in Chemehuevi (Uto-Aztecan) (Press 1980), Zimakani (Trans New Guinea) (Voorhoeve 1970), and Turkana (Nilotic) (Dimmendaal 1983), and adjacent to non-high vowels in Yakut (Turkic) (Krueger 1962; Nevins and Vaux 2004b). A local version of the same palatalization process as Harari is found in the related language Amharic (Semitic) (Leslau 1995). Faucal harmony appears to have an affinity with vowel-consonant harmony, but the other two cases share a stronger resemblance to consonant harmony. Dorsal harmony is described in Section 2.1.4 and Hansson (2001b, 2010) provides cases of palatal alternations that involve stops and fricatives. None of these cases exhibit blocking effects. Finally, the Sibe and Harari cases are triggered by or target specific affixes.

2.4 Vowel Harmony

Vowel harmony refers to assimilations among vowels. The assimilating vowels may be separated by consonants. Vowel harmony typically occurs within a word or smaller domain. Assimilations are observed for individual features and for feature clusters. We discuss examples of harmony for backness, rounding, height, and tongue root advancement/retraction, as well as harmony for all vowel place features. We use “vowel place” as a cover term to refer to features that are typically classified as vocalic, that is, ones applicable to backness, rounding, height, and tongue root posture.

There have been numerous valuable comparative studies of vowel harmony. Cumulatively, these have given shape to our understanding of the range of patterns across languages and the surrounding theoretical issues. Some examples of cross-linguistic generative studies cross-cutting several vowel harmony types include Kiparsky (1973c), Ringen (1975 [1988]), McCormick (1982), Goldsmith (1985), Cole (1987), Calabrese (1988, 1995, 2005), van der Hulst (1988b), Odden (1991), van der Hulst and van de Weijer (1995), Li (1996), Majors (1998), Polgárdi (1998), Krämer (2003), Nevins (2004), and Archangeli and Pulleyblank (2007), among many others. We point to some studies focused on harmony for a particular feature or feature group where relevant below.

2.4.1 Backness Harmony Tuvan (Turkic) shows a backness (palatal) harmony (Anderson and Harrison 1999; Harrison 1999, 2000). Tuvan presents eight vowel qualities, as shown in (26). Vowels may be long or short.

(26)		<i>Front</i>	<i>Back</i>
	<i>High</i>	i y	ɯ u
	<i>Non-high</i>	e ø	a o

In native Tuvan words, vowels in a word are alike in backness, being drawn either from the set of front vowels (27a) or back vowels (27b).⁷ The harmony produces alternations in suffix vowels, which take their cue from the backness of the preceding vowel, as shown in (27c). Within roots, there is reason to postulate that backness harmony is progressive. The evidence comes from epenthetic vowels in word-medial syllables of a disharmonic loan; these vowels harmonize with the vowel of the preceding syllable rather than the following one, for example, *texinɑ:r* (from Russian *tex'nar* ‘grain alcohol’), *partuʃel* (from Russian *partʃel* ‘wallet’).

(27)	a.	<i>ivi</i>	‘deer’
		<i>idegel</i>	‘hope’
		<i>xylymzyre:r</i>	‘smile’ FUT.
		<i>e:ren</i>	‘totem’
		<i>xø:mej</i>	‘throat singing’

b.	urak	'far'
	ulu	'dragon'
	ajur:l	'danger'
	oruk	'road'
c.	is-ter-im-den	'footprint' PL-1-ABL.
	at-tar-um-dan	'name' PL-1-ABL.
	esker-be-di-m	'notice' NEG-PST.II-1
	udu-va-duu-m	'sleep' NEG-PST.II-1

In this system, harmony is fully combinative: every vowel can be a trigger and a target for backness harmony. Many languages with backness harmony belong to the Ural-Altai family. Well-examined cases include Turkish (e.g. Clements and Sezer 1982), Hungarian (Vago 1973, 1974; Ringen 1975 [1988]), and Finnish (e.g. Kiparsky 1973c; Ringen 1975 [1988]) (with numerous subsequent studies).

2.4.2 Round Harmony A cross-linguistic survey of round harmony is found in Kaun (1995, 2004). An example of round harmony occurs in the Halh (Khalkha) dialect of Mongolian (Mongolic) (Svantesson *et al.* 2005). Vowel phonemes of Halh are given in (28). The vowels on the right are characterized as pharyngeal. Their tongue root is pulled back and there is possible involvement of the pharyngeal constrictor muscles (Svantesson 1985; Svantesson *et al.* 2005). The pharyngeal characterization amounts roughly to the retracted tongue root feature specification [(+)RTR].⁸ Vowel length is contrastive for all vowels, except that short [e] occurs only in non-initial syllables. In non-initial syllables, vowels are full or reduced.

(28)	<i>Non-pharyngeal</i>		<i>Pharyngeal</i>	
	<i>Unround</i>	<i>Round</i>	<i>Unround</i>	<i>Round</i>
<i>High</i>	i	u	a	ɔ
<i>Non-high</i>	e	o	a	ɔ

Round harmony occurs among non-high vowels only, producing suffixal alternations between e/o and a/ɔ, as shown in (29a). A pharyngeal harmony is also seen in these data. High round vowels do not trigger round harmony and they block it from a preceding non-high round vowel (29b). However, /i/ is transparent. It may intervene between harmonizing non-high vowels while remaining unround itself (29c). If /i/ is the only stem vowel, the suffix is unround (29d). When round harmony is prevented, non-high vowels are unround in non-initial syllables.

(29)	a.	og-ɣo	'to give' DPST.
		xe:ɣ-ɣe	'to decorate' DPST.
		ɔr-ɣo	'to enter' DPST.
		jaw-ɣa	'to go' DPST.
	b.	su:ɣ-e	'tail' REFL.
		mʊ:r-a	'cat' REFL.
		og-uɣ-ɣe	'to give' CAUS-DPST.
		ɔr-uɣ-ɣa	'to enter' CAUS-DPST.

- | | | |
|----|-----------|--------------------|
| c. | po:r-ig-o | 'kidney' ACC-REFL. |
| | xo:ɬ-ig-o | 'food' ACC-REFL. |
| | oɬi-ɬo | 'to squint' DPST. |
| d. | pi:r-e | 'brush' REFL. |
| | it-ɬe | 'to eat' DPST. |

It is noteworthy that Halh round harmony restricts triggers to non-high vowels. In addition, it shows an identity effect in that the harmonizing vowels must match in height (Kaun 1995, 2004).

Languages that show round harmony often also show harmony for another feature. A number of languages show both round harmony and backness harmony. Turkish (Turkic) is a well-studied case (e.g. Clements and Sezer 1982). Other examples include Tuvan (Harrison 2000), Tunica (Gulf) and Ewe (Kwa) (Odden 1991). Round harmony occurs together with pharyngeal (or [RTR]) harmony in several Mongolic languages (Svantesson *et al.* 2005) and with [RTR] harmony in certain Tungusic languages (Li 1996). Round harmony is reported to occur with ATR harmony in the Niger-Congo languages, Chumburung, Dagaare, and Igbo (van der Hulst and van de Weijer 1995; Krämer 2003), but as Krämer points out it is possible to analyze the harmonizing feature as [back] in place of [round].

2.4.3 Height Harmony Generative cross-linguistic studies dealing with vowel height harmony include Goad (1993) and Parkinson (1996). Kisa (Bantu) presents a harmony that causes lowering of high vowels (Sample 1976; Hyman 1998, 1999). Kisa's vowel inventory consists of [i e a o u]. Each vowel may be short or long. As shown in (30), the vowel in the suffix /-il/ lowers to mid when preceded by a mid vowel in the stem. The suffix remains high following a syllable with a high vowel or low [a].

- (30) *Applicative*
- | | |
|-------------|---------------------------|
| -tsom-el-a | 'pierce' |
| -rek-el-a | 'set trap' |
| -βis-il-a | 'hide' |
| -fu:ng-il-a | 'lock' |
| -βa:mb-il-a | 'spread out, fasten down' |

When the target vowel is /u/, height harmony occurs only if the trigger is /o/ not /e/, as shown in (31) with the reversive transitive suffix /-ul/. This rounding restriction is another example of an identity effect.

- (31)
- | | |
|-------------|-------------------------|
| -tsom-ol-a | 'pull out' |
| -rek-ul-a | 'spring trap' |
| -βis-ul-a | 'reveal' |
| -fu:ng-ul-a | 'unlock' |
| -βa:mb-ul-a | 'spread apart, open up' |

The Asturian dialect of Lena (Romance) shows a height harmony that involves raising (Hualde 1989a). The vowel inventory is /i e a o u/. In Lena, a high vowel in an inflectional suffix causes raising of a preceding non-high stressed vowel. The height harmony is stepwise: /e o/ raise to [i u] (32a) and /a/ raises to [e] (32b).⁹ High stressed vowels are unaffected (32c).

(32) a.	ka'biθu	ka'beθos	'head' M.SG./M.PL.
	fon'diru	fon'dera	'lower' M.SG./F.SG.
	re'undu	re'ondo	'round' M.SG./MASS.
	'tsubu	'tsobos	'wolf' M.SG./M.PL.
b.	'eltu	'alta	'tall' M.SG./F.SG.
	ben'tenu	ben'tanos	'window' M.SG./M.PL.
c.	ka'britu	ka'brita	'kid, young goat' M.SG./F.SG.
	'kubu	'kubos	'pail' M.SG./M.PL.

Lena's harmony demonstrates certain types of restrictions on triggers and targets. Targets must be stressed. Comparative studies in the generative tradition of height harmonies that affect stressed targets include Calabrese (1985), Hualde (1989a), Kaze (1989), Flemming (1993), Dyck (1995), and Walker (2005). Harmonies where a post-tonic high vowel causes raising of a stressed vowel are traditionally referred to as *metaphony* in Romance. Similar patterns involving fronting (and sometimes also raising) are referred to as *umlaut*, especially in Germanic. Triggers in Lena are subject to a morphological restriction: they must belong to an inflectional affix. This is evidenced by the form [sili'kotikos] 'suffering from silicosis' M.PL., where post-tonic /i/ in the stem does not trigger raising of the stressed vowel. Compare [sili'kutiku] M.SG., which shows that the stressed stem vowel does raise when the word contains an inflectional high vowel.

Harmony for the feature [low] is much less common cross-linguistically. Among patterns that have been treated as [low] harmony, controversy exists about the choice of feature. Relevant discussion can be found in van der Hulst (1988b), Clements (1991), Goad (1993), Archangeli and Pulleyblank (1994), Beckman (1995), van der Hulst and van de Weijer (1995), Casali (1996 [1998]), Parkinson (1996), Pulleyblank (1996), Hyman (1999), and Paster (2004), among others. For some harmony systems, there is debate about whether height features and [ATR] are both involved, as we discuss in Section 3.3.2.

2.4.4 Tongue Root Harmony The Pulaar dialect of Fula (Niger-Congo) shows a tongue root harmony (Paradis 1992; Archangeli and Pulleyblank 1994). Pulaar presents seven vowels, [+ATR] [i e o u] and [-ATR] [ɛ a ɔ].¹⁰ In non-final position, the mid vowels' [ATR] specification is determined by the following vowel, producing alternations between e ~ ε and o ~ ɔ (33a). [ATR] harmony targets neither the high nor low vowels, causing potential disruptions in the harmonic sequence, but these vowels still trigger harmony in the preceding syllable (33b).

- (33) a. m be:l-u m be:l-ɔn ‘shadow’ SG./DIM.PL.
 pe:c-i pe:c-ɔn ‘slit’ PL./DIM.PL.
 dog-o:-ru n dɔg-ɔ-w-ɔn ‘runner’ SG./DIM.PL.
 lef-el lef-ɔn ‘ribbon’ CL.8.DIM.SG./CL.21.DIM.PL.
 ce:lt-ol ce:lt-ɔn ‘cut’ CL.9/CL.21.DIM.PL.
- b. βet-ir-dɛ ‘weigh with’ βet-dɛ ‘weigh’
 dɔkk-id-dɛ ‘become one-eyed’ dɔkk-ɔ ‘one-eyed person’
 feff-u-dɛ ‘fell’ feff-a ‘fell’ IPFV.
 bo:t-a:-ri ‘lunch’ *bo:t-a:-ri
 n gɔr-a:-gu ‘courage’ * n gɔr-a:-gu
 kelan n gel ‘break’ DIM *kelan n gel

Pulaar exemplifies a cross-linguistically common avoidance of [+ATR] low vowels and [-ATR] high vowels (Calabrese 1988; Archangeli and Pulleyblank 1994). As a result, tongue root harmony systems show a greater tendency to affect mid vowels.

Some tongue root harmonies exhibit what is known as a *dominant* pattern. An example is found in Maasai (Nilotic) (Tucker and Mpaayei 1955; Archangeli and Pulleyblank 1994; Baković 2000, 2002). Maasai has nine vowels [i i e ε a ɔ o u u]. In ATR harmony, affixes show alternations in conformity with the root’s ATR specification (34a) (roots are underlined). Some suffixes are invariably [+ATR], and these cause the root and prefixes to become [+ATR], as shown by alternations in (34b).

- (34) a. /kɪ-norr-u/ kinorru ‘we shall love’
 /kɪ-idim-u/ kɪdɪmɔ ‘we shall be able’
 /mɪ-kɪ-itoki/ mikintoki ‘we shall not do again’
 /mɪ-kɪ-ran/ mikɪrɔn ‘let us not sing’
- b. /ɪsuj-ɪfɔ-re/ ɪsujɪfore ‘wash with something!’
 /ɪsuj-ɪfɔ/ ɪsujɪfɔ ‘wash!/do the washing!’
 /a-rɔk-u/ aroku ‘I become black’
 /a-tV-rɔk-a/ atɔrɔka ‘I became black’

In this pattern [+ATR] is known as *dominant* and [-ATR] as *recessive*. Patterns such as this are often characterized as ones in which the presence of an underlying specification for the dominant feature causes all vowels in the word to become [+ATR] (e.g. Cole 1987). Maasai and other dominant [+ATR] systems show directional asymmetries with respect to blocking by the low vowel /a/. See Section 4.1 for discussion.

Generative cross-linguistic studies of tongue root harmony include Archangeli and Pulleyblank (1994), Pulleyblank (1996), Zhang (1996), and Baković (2000). Some tongue root harmonies are treated as involving privative or binary [ATR] and likewise others as involving [RTR]. Li (1996) argues RTR and ATR vowel systems show typological differences in harmony patterns as well as in inventories and their historical development. He maintains that canonical Tungusic vowel

harmony is an RTR system, whereas typical ATR systems are widespread in African languages.

2.4.5 Complete Harmony Some harmony systems show assimilation for all vowel quality features, often referred to as *vowel copy* harmony. As discussed by Steriade (1987a), many patterns of this kind are restricted to vowels separated by no more than a laryngeal segment. Kashaya (Pomoan) (Buckley 1994) exhibits a translaryngeal harmony that produces vowel identity in native morphemes, as shown in (34a). Supralaryngeal consonants block harmony (35b).

- (35) a. mihi'la 'west'
 we'ʔej 'yonder'
 waʔali 'cane'
 so'hoj 'seal'
 hu'ʔul 'a while ago'
- b. biʔdu 'acorn'
 hoja 'scoring sticks'
 k'aʔli 'between'
 ho'p^hune 'white-footed mouse'

In some systems, harmony that produces identical vowels operates across other segments. Transguttural harmony (Rose 1996) is attested in Jibbāli (Semitic) (Hayward, Hayward, and Al-Tabūki 1988) and Iraqw (Cushitic) (Mous 1993), and vowel copy harmony occurs across coronal consonants in certain morphological contexts in Pulaar (Paradis and Prunet 1989).

To conclude, vowel harmony occurs for all of the primary vowel place characteristics, affecting backness, rounding, height, and tongue root advancement/retraction. Some harmonies show assimilation for feature clusters. Assimilation for all vowel place features is attested, although it is prone to restrictions on the intervening consonants – a condition seen less frequently for vowel harmonies that involve only a subset of features. In contrast, consonant harmony involving major place features is not attested in adult language. Likewise, vowel-consonant harmony is restricted to properties that are compatible with both consonants and vowels, which can include characteristics of vowel place – realized as a secondary articulation on a consonant – but does not include major consonant place.

3 Analyses of Principal Aspects of Harmony Systems

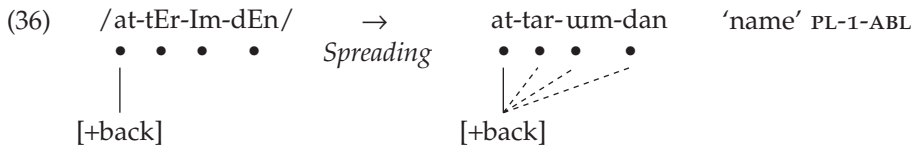
3.1 Autosegmental Representations

Autosegmental representations form the backbone of traditional non-linear analyses of harmony systems. We first review these accounts' primary features and then describe subsequent theoretical modifications and proposals. Recent progress points towards a greater diversity than previously conceived in the formal

motivations for harmony and the types of representations involved. These emerging differences motivate our discussions separately of advances in the analysis of (i) consonant harmony, (ii) vowel harmony and local vowel-consonant harmony, and (iii) non-local vowel-consonant harmony.

3.1.1 Spreading With the advent of non-linear phonology, the analysis of harmony systems as autosegmental spreading widely took hold (Goldsmith 1976a [1979]; Clements 1980). This marked a significant advance that directly or indirectly underlies many present-day treatments of particular harmony patterns.

In autosegmental representations, each harmonizing feature exists on its own tier. A feature's affiliation with a segment is represented by an association line which links the feature to the root node or to a node in the segment structure that the root dominates.¹¹ In autosegmental spreading, a feature links to additional segments, representing the fact that those segments have undergone assimilation for the feature. Spreading of [+back] from the root to suffix vowels in a Tuvan word is illustrated in (36). Bullets represent whatever node dominates [+back] in the segment structure. By convention, the broken line symbolizes a new association. For purposes of demonstration, we show nodes and linkage for vowels only here, returning to the status of consonants later. In the underlying form, we identify a suffix high vowel with *I* and a non-high vowel with *E*, indicating that they do not contribute an independent [\pm back] specification – that is determined by the vowel in the preceding syllable.

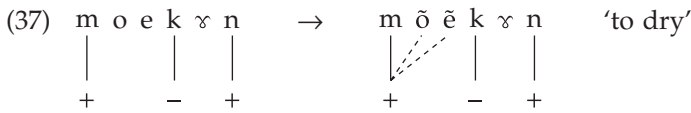


In autosegmental approaches to harmony, certain constraints or conditions on representations can be responsible for effects such as blocking and transparency, as we discuss below.

3.1.2 Targets, Blockers, and Transparent Segments Segments which block or are transparent to harmony are assumed to deviate from a canonical target. Targets can be identified through restrictions expressed in terms of autosegmental representations. For instance, targets could be restricted to segments that lack a pre-existing specification for the harmony feature, which is known as a *feature-filling* pattern. In approaches assuming an elaborated feature geometry, targets could be segments with the node that immediately dominates the spreading feature (e.g. Sagey 1986 [1991]; Steriade 1986; Archangeli and Pulleyblank 1987; Odden 1991), that is, they present a *target node*. Targets could additionally be subject to a requirement that they bear a certain feature specification. For example, round harmony in Turkish affects high vowels only; this could be analyzed with a restriction that the target be [+high] (or [-low]) (Goldsmith 1990).

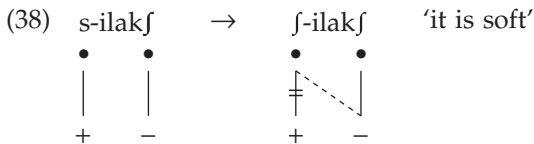
Both vowel harmony and local vowel-consonant harmony are subject to blocking; blocking segments are described as *opaque*; we prefer the term *blocker* to minimize confusion with other cases of phonological opacity. The blocker segment halts harmony and in most cases does not undergo assimilation itself.

Early autosegmental accounts of blocking assumed that blockers are specified with the non-spreading value, for example [-nasal] if [+nasal] is spread. In their account of nasal harmony, van der Hulst and Smith (1982) propose that obstruents (or other blockers depending on the language) project a bound autosegment [-nasal]; [+nasal] associates to other segments via spreading until it encounters an association line, as shown for Sundanese in (37). The targets are the segments lacking nasal specification. The +/- specifications are shown here for the [nasal] feature tier.



Essential to this treatment of blocking is the proposal that autosegmental representations are subject to the No-Crossing Constraint (NCC), which prohibits crossed association lines (Goldsmith 1976a [1979]). The NCC prevents a given feature from spreading over a feature specified on the same tier. A segment that is already specified for a feature on the tier on which spreading takes place can therefore block harmony (e.g. [k] in (37)), because spreading over that segment would cause line crossing. The NCC is widely assumed to be a “hard” universal, that is, it is never violated in linguistic structures.

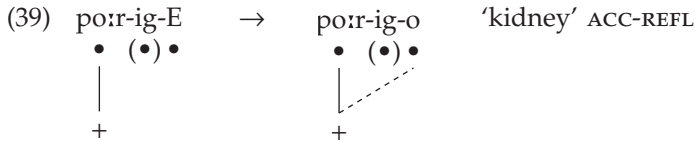
Prespecification for the harmonizing feature does not always guarantee blocking. Some harmonies are characterized as *feature-changing*, which means that harmony can change a segment’s specification for the assimilating feature. Sibilant harmony in Ineseño Chumash has been analyzed as feature-changing (Poser 1982, 1993; Lieber 1987; Shaw 1991), because they argue that both values of the relevant feature must be underlyingly specified. As discussed in Section 2.1.1, harmony causes /s/ to become [ʃ] and /ʃ/ to become [s], that is, when a sibilant is not followed by another sibilant in the word with which it must harmonize, its tongue tip-blade feature is contrastive and triggers harmony. An analysis of spreading [anterior] is illustrated in (38) (Shaw 1991).



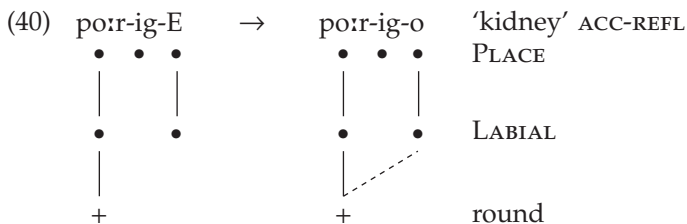
In a feature-changing operation, the target acquires a feature specification and loses an existing one by removing its association line (usually followed by elimination

of the delinked feature). Delinking allows the NCC to be respected in the event that harmony persists onwards.

Whereas the absence of a specification for the harmonizing feature could cause a segment to be a target, it could also cause it to be transparent under an analysis that involves a *gapped* representation. A gapping analysis is illustrated in (39) for Halh round harmony. The spreading of [+round] skips transparent /i/ and reaches into the following suffix with a non-high vowel, that is, feature association gaps across /i/. (Assumptions vary as to whether association is regarded as gapping across the consonants here, as we discuss below.) A transparent vowel's failure to be targeted could be handled in various ways. For example, it could lack the target node or a feature specification that is a requirement for targets; alternatively, a markedness constraint could prevent formation of the vowel that would result if it were targeted.



A matter closely tied to transparency concerns locality restrictions on a feature's associations. Proposals have been made in which harmony phenomena can be parameterized according to the autosegmental tier or level of prosodic structure at which a trigger and target must be adjacent. For example, locality may be defined at the level of vowel nuclei or morae of adjacent syllables, allowing for transparent consonants in vowel harmony (Archangeli and Pulleyblank 1987, 1994). The theory of locality advanced by Odden (1994a) includes adjacency parameters that may require targets and triggers to belong to adjacent syllables or to have adjacent root nodes. Locality defined at tiers below the root in the feature geometry allows for transparent vowels in vowel harmony or transparent consonants in consonant harmony. Segments not specified on the relevant tier do not enter into the computation of locality. Transparent [i] in the Halh example above would thus lack particular feature specifications, as shown in (40) (the feature geometry shown is that of Sagey (1986 [1991]), but this is not essential). Here, the two mid vowels are "local" on the LABIAL tier.



Piggott (1996) proposes that harmony can take the form of a relation that holds at the suprasegmental levels of syllable or foot, and locality is defined in terms of

these categories (see also Piggott and van der Hulst 1997; Piggott 2003). Harmony must affect at least one segment within the syllable or foot domain, opening the possibility that certain other segments (e.g. obstruents in nasal vowel-consonant harmony) may be unaffected and hence transparent.

The well-formedness of gapped configurations has been questioned, spurring new analytical directions. Some work defines gapped configurations as ones where feature linkage skips over an eligible *anchor*, for example, a mora in vowel harmony (Archangeli and Pulleyblank 1994; Pulleyblank 1996). Under this interpretation, feature association in vowel harmony could skip over consonants in syllable margins but not vowels in syllable heads. Other analyses have taken the position that gapping may not occur across any segment (e.g. Ní Chiosáin and Padgett 1997, 2001; Walker 1998 [2000]; Rose and Walker 2004; Gafos 1996 [1999], 1998b makes a similar claim expressed in terms of articulatory gestures).¹² Approaches that make these locality assumptions must analyze (certain) transparency effects in ways other than the harmonizing feature skipping the transparent segment, as we discuss below.

3.2 *Analyses of Consonant Harmony*

Consonant harmony in generative phonology has also traditionally been analyzed using autosegmental spreading. Recent advances in the analysis of consonant harmony question this assumption and the underlying premise that harmony systems share particular characteristics (Hansson 2001b, 2010; Rose and Walker 2004). This is based on (i) a richer understanding of the range and typology of consonant harmony systems, (ii) a lack of blocking effects, and (iii) similarity between interacting consonants.

An autosegmental spreading analysis of consonant harmony must address the transparency of vowels and other consonants. Steriade (1987b) argued that intervening consonants and vowels in Ineseño Chumash sibilant harmony lack specification for the feature [anterior], a feature relevant only for coronals. This excludes vowels, dorsals, and labials from participation in the harmony, but the transparency of coronal consonants /t l n/ must be explained. This is achieved through underspecification. The sibilants contrast for [anterior] but /t l n/ do not have [-anterior] counterparts, and so are predictably [+anterior]. Predictable features are left unspecified. Harmonic spreading of the [anterior] feature operates unhindered between sibilants before a redundancy rule fills in predictable values on the other coronals. Shaw (1991) further argues that locality is defined on the [anterior] tier, so only segments specified for [anterior] (i.e. the sibilants) are involved in the locality calculation.

Shaw (1991) provides a taxonomy of consonant harmony systems which identifies two predominant systems: coronal harmony (=sibilant harmony) and laryngeal harmony.¹³ This typology is in line with expectations concerning locality (or tier-based spreading) and underspecification. Features that are distinctively specified on consonants define an autosegmental tier not utilized by vowels, and these are precisely the features predicted to participate in consonant harmony. Segments

unspecified for such features should be transparent to harmony. Under a feature system in which vowels are specified as dorsal (Sagey 1986 [1991]; Steriade 1987a)¹⁴ coronal consonants do not share features with vowels. Laryngeal features are used to distinguish among consonants but not vowels. Sonorants are inherently voiced, so they do not require specification of the feature [voice] (Itô and Mester 1986). The additional harmony types (dorsal, nasal, liquid) identified in Hansson (2001b, 2010) and Rose and Walker (2004) were not included in Shaw's typology, and were predicted not to occur. Yet, dorsal harmony would interfere with vowel specifications, and the features [nasal] and [lateral], being dependent on the root node in the feature geometry, were predicted not to spread across other segments.

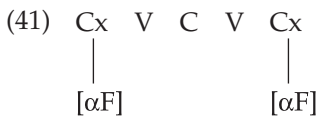
Gafos (1996 [1999]) rejects tier-based locality, and argues that locality is defined in terms of articulatory gestures. Vowel gestures are contiguous across a consonant, whereas consonant gestures are not contiguous across a vowel (see also Ní Chiosáin and Padgett 1997, 2001). Given this version of locality, only coronal harmony, which involves assimilation for a tongue tip-blade feature, is predicted to be possible, as this is the only type of harmony which would not interfere with vowels. The tongue tip-blade is independent of the tongue dorsum used in the production of vowels, and its exact posture has no significant acoustic effect on vowel quality. Gafos proposes that tongue tip-blade features (Tongue Tip Constriction Orientation (TTCO) and Tongue Tip Constriction Area (TTCA)) do not skip over other segments, but are maintained through them with little perceptible effect. Coronal segments /t n l/ in Chumash harmony are predicted to alter their production in accordance with the harmonic domain in which they occur, either apical [ɲ] in words like /k-sunon-us/ → [ksunonus] 'I obey him' or laminal [ɲ] in words like /k-sunon-f/ → [kʃunotʃ] 'I am obedient'. As stops do not contrast on this dimension in Chumash, they are not perceived as distinct. Other consonant harmony types (nasal, dorsal) are predicted not to occur, as they would involve interference with the tongue dorsum and other articulators.

However, Hansson (2001b, 2010) and Rose and Walker (2004) show that consonant harmonies are not restricted to coronals. Faced with a wider range of examples, both studies conclude that autosegmental spreading is inadequate as a model of consonant harmony. Consider nasal consonant harmony, as discussed in Section 2.1.2. Nasal consonants harmonize with voiced stops or sonorant consonants across other consonants and vowels. Yet, intervening vowels are unaffected by harmony and do not block, whereas in vowel-consonant nasal harmony, vowels are the prime targets of nasal harmony. They also can serve as triggers and some vowels may even block nasal harmony. Nasal consonant harmony does not behave as if autosegmental spreading of [nasal] is involved. Hansson (2001b, 2010) and Rose and Walker (2004) identify several key properties of consonant harmony which differentiate it from vowel-consonant harmony and vowel harmony. First, there are no blocking effects (although see Hansson 2007a). Second, the triggers and targets bear a high degree of similarity to one another. Third, Hansson (2001b, 2010) argues that there is no sensitivity to prosody in consonant harmony. Fourth, Hansson (2001a, b) argues that the predominant directional pattern in consonant harmony is right-to-left or regressive. There is no directionality tendency with

vowel-consonant harmony or vowel harmony (although see Hyman 2002). All of these factors point to an alternative perspective.

Hansson (2001a, b) and Rose and Walker (2004) propose that similarity is the driving factor in consonant harmony, and has its functional roots in speech production. Similar, but different, consonants present production difficulties that appear in speech errors (e.g. Fromkin 1971; Shattuck-Hufnagel and Klatt 1979; Frisch 1996). Sibilants are highly similar to one another and it is hypothesized that production is eased if they match for the position of the tongue tip-blade. Nasal stops harmonize with oral sonorants or voiced stops, which differ minimally from nasals. Voicing agreement occurs between obstruents, but is often restricted to stops. Homorganicity further contributes to similarity, and some laryngeal and nasal harmonies only operate between homorganic segments.¹⁵ Rose and Walker (2004) determine similarity using the metric developed in Frisch, Pierrehumbert and Broe (2004). This metric assesses similarity based on shared natural classes of distinctive features in a given language by comparing the number of shared and unshared natural classes of two consonants. The size and contrastiveness of the segment inventory contributes to the similarity ratings. Natural classes, which incorporate the notion of contrastiveness, are better able to predict gradient phonotactics and capture major class subregularities than models based simply on distinctive feature specification. See also MacKenzie (2005) on the advantage of contrast-based similarity calculations.

Based on Walker (2000a, b), Hansson (2001b, 2010) and Rose and Walker (2004) develop an account of consonant harmony within Optimality Theory (OT), termed “agreement-by-correspondence,” that establishes a correspondence relationship between similar segments, expressed as CORR-C↔C constraints, and indicated in the diagram below by coindexation. There is no autosegmental feature linkage between the segments.¹⁶



The CORR-C↔C constraints are arranged in a fixed implicational hierarchy from most similar to least similar. IDENTITY-CC constraints require the corresponding consonants to agree. Input-output faithfulness constraints can be placed between the CORR-C↔C constraints. The following tableau illustrates an example of nasal harmony in Kikongo (Bantu) for the word /futumuk-idi/ → [futumukini] ‘resuscitated’ (INTR) (Déreau 1955; Ao 1991).¹⁷ The tableau shows only the stem and suffix portion of the word in which nasal harmony occurs. CORR-N↔D refers to homorganic nasal and voiced stop pairs, and CORR-N↔B to homorganic and heterorganic nasal-voiced stop pairs. Candidate (42b) has no correspondence relationship between /m/ and /d/, whereas candidate (42c) does, and the segments do not agree for nasality. Candidate (42a) has both a correspondence relationship and nasal agreement. It violates IDENT-OI(nas), which is violated by segments that gain a privative [nasal] specification in the output.

(42)

/futumuk-idi/	IDENT-CC (nas)	CORR-N↔D	CORR-N↔B	IDENT-OI (nas)
a. futum _x ukin _x i				*
b. futum _x ukid _y i			*!	
c. futum _x ukid _x i	*!			

No correspondence relationship is established between the nasal and the voiceless stop /k/, as these two sounds are not sufficiently similar. Harmony in Kikongo operates between heterorganic segments, but if harmony were restricted to homorganic segments, the IDENT-OI constraint would occur between the homorganic CORR-N↔D and heterorganic CORR-N↔B constraints, causing candidate (42b) to win. Other work analyzing particular consonant harmony systems as involving corresponding segments or feature copy includes Clements (2001) and McCarthy (2007a).

The correspondence-based approach to consonant harmony allows similar consonants to agree at a distance; transparent segments are those that are not similar enough to participate in the harmony. No blocking is predicted, as lack of harmony is due to lack of/low ranking of correspondence with intervening segments.¹⁸ This approach sets consonant harmony apart from vowel harmony and vowel-consonant harmony in using a different analytical mechanism.¹⁹

In conclusion, a more accurate typology of consonant harmony has led to alternate analytical devices using correspondence-based relations rather than autosegmental spreading. The assumption that all harmony systems are alike and therefore subject to the same type of analysis has been called into question, representing a significant departure in the analysis of consonant harmony and of harmony systems in general.

3.3 Analyses of Vowel Harmony and Local Vowel-Consonant Harmony

3.3.1 Harmony Imperative Whereas growth in our knowledge of the typology of consonant harmony points away from autosegmental spreading as a source for these systems, the situation is different for vowel harmony and local vowel-consonant harmony. In the majority, continued research on the latter harmony types supports representations for these systems in which a single occurrence of the harmonizing element is present throughout the sequence of segments (or anchors) that undergo assimilation. Most often this is modeled in terms of multiple linkage of an autosegmental feature. Some analyses based in the representations of Articulatory Phonology (Browman and Goldstein 1986, 1989, 1990) postulate gestures instead of features. Harmony is then analyzed as the temporal extension of a particular gesture over the interval that presents harmony (e.g. Gafos (1996 [1999])).

While analyses in rule-based phonology posit a spreading rule for the harmonizing feature, harmony is analyzed as driven by constraints in OT. Which type(s) of constraint are the cause of feature spreading is a topic of active debate. Among the issues at play are (i) whether harmony is driven by a spreading-specific constraint or is an epiphenomenon of independently motivated constraints, (ii) whether the constraint reflects a hypothesized phonetic basis for harmony, and (iii) the closeness-of-fit of predicted and attested patterns.

3.3.1.1 *Spreading Constraint or Epiphenomenon?* Vowel harmony and local vowel-consonant harmony have frequently been analyzed as driven by a constraint that requires features to align to a domain edge, such as the word, with spreading being the result. The feature alignment approach, first proposed by Kirchner (1993) for vowel harmony, is an extension of the Generalized Alignment constraint schema put forward by McCarthy and Prince (1993a). Applied to a backness harmony system, such as Tuvan’s, the constraint would be ALIGN-R([back], word), requiring that any [back] specification in a word be associated with the rightmost syllable (or segment) in the word. The constraint is interpreted as satisfied when the rightmost association of a [back] feature coincides with the rightmost syllable. Assuming that all vowels have a specification for backness, this constraint favors outputs in which all vowels are linked to a single specification for [back]. The basic analysis is illustrated in (43) with the Tuvan word [at-tar-uum-dan] ‘name’ PL-1-ABL.²⁰ For demonstration purposes, a hypothetical input is considered in which one of the suffixes is specified [-back].

(43)	/at-tEr-im-dEn/ + -	ALIGN-R([back], word)	IDENT-IO(back)
☞ a.	at-tar-uum-dan + -		***
b.	at-tar-im-den + -	*!*	**
c.	at-ter-im-den + -	*!***	**

The winner in (43a) with full back harmony aligns the [+back] specification of the root to the right syllable of the word. A constraint not shown that enforces root faithfulness (e.g. McCarthy and Prince 1995; Beckman 1998 [1999]) is assumed to ensure preservation of the root’s [back] specification. Further, a constraint on

locality is assumed to prevent feature linkage from skipping intervening syllables. Candidate (43b) spreads [+back] from the root to its neighboring suffix, and [-back] from the second suffix to the final syllable. This candidate violates the alignment constraint, because the [+back] specification is not right-aligned in the word. A gradient assessment is posited, such that a violation is accrued for each phonological unit by which a [back] specification is misaligned. Here, the unit is assumed to be the syllable, although in some analyses it could be the mora or segment. Candidate (43c) presents bidirectional spreading to neighboring suffixes from the second suffix. Like (43b), this candidate fails because it violates alignment. It accrues three violations because [+back] is misaligned by three syllables from the word's right edge.

Drawing on a proposal by Padgett (1995b), some analyses have formulated the spreading imperative as a constraint (SPREAD(F)) that requires a feature specification to be linked to all segments in a given domain. This approach does not stipulate directionality, allowing apparent directionality effects to follow from other properties of the system, such as positional faithfulness (e.g. Walker 2001b; Padgett 2002; see Kaun 1995 for a similar approach). Harmony patterns that show what is arguably true directionality has been analyzed with a directional version of a SPREAD constraint, as discussed in Section 4.1 below.

Also based in autosegmental representations is the *feature-driven markedness* analysis of harmony (Beckman 1997, 1998 [1999]), which seeks to subsume spreading-based patterns under constraints independently required for a variety of featural markedness effects. An essential claim is that violations of feature markedness constraints **F* are assessed at an autosegmental level. In other words, a constraint such as *[back] incurs a violation for each [back] specification in the representation, without reference to the number of segments with which each [back] specification is associated. Violations of *[back] can be minimized when a single feature is associated to all vowels in a word, thereby causing feature spreading.

The AGREE(F) approach departs from treatments of vowel harmony (and other assimilations) that intrinsically demand multiple associations of a single autosegment. The AGREE(F) constraint requires that adjacent elements have identical specifications for a feature without requiring that they share a feature specification (e.g. Lombardi 1999; Baković 2000).²¹

All of these approaches to the harmony imperative are typically non-specific about targets.²² For example, alignment constraints cause feature spreading to seek a word edge rather than a particular target segment type. The lack of emphasis on targets is replaced by constraints that prevent certain segments from undergoing harmony. For example, the feature co-occurrence constraint *[+round, -high] prevents round harmony in Turkish from targeting non-high vowels (for discussion of this constraint, see Section 3.3.3).

This strategy differs from rule-based formalizations of the harmony imperative which permit positive target restrictions, for example requiring that targets be specified for a particular feature. In the case of Turkish round harmony, the target is required to be [+high] (see Section 3.1.2), thereby focusing on the segments that the assimilation affects. In the parametric rule formalism of Archangeli and Pulleyblank (1994), rules may include target conditions. These may be implicational

grounded path conditions, which govern well-formedness, for example, ATR/LO: 'if [+ATR], then [-low]'. These restrict targets to segments that obey the implication when they undergo the assimilation. Grounded conditions are similar in spirit to OT accounts in which markedness constraints prevent certain segments from undergoing harmony.

3.3.1.2 Phonetic Bases for Harmony A branch of research that has made significant advances in recent years centers on phonetic bases for harmony, and in some cases this has influenced the formalization of the harmony-driving constraint. Several studies have emphasized this topic. Hypothesized grounding or origins in phonetics fall broadly into two categories, perceptual and articulatory.

In the area of perceptual factors, certain vowel harmonies are identified as triggered by vowels with contrastive properties that have comparatively weak perceptual cues (e.g. Kaun 1995, 2004; Walker 2005b; see Suomi 1983 for related discussion). For example, Kaun argues that rounding is more perceptually subtle in non-high vowels than in high ones, causing non-high vowels alone to trigger round harmony in some patterns, such as Halh. The assumption that underlies this is that vowel harmony is primarily a perceptually driven phenomenon, an idea put forward by Suomi (1983). Harmony serves to increase the duration of the rounding feature, thereby enhancing the probability that it will be accurately perceived. Further, some harmonies are asymmetrically triggered by vowels in perceptually impoverished contexts (Ringen and Vago 1998; Walker 2005). For instance, metaphony-type harmonies are triggered by post-tonic vowels, often inflectional ones only (see Section 2.4.3). Harmony improves exposure of the harmonic feature either by extending it over a longer domain and/or by realizing it on a stressed vowel. In work on nasal vowel-consonant harmony, Sanders (2003) hypothesizes that certain patterns are motivated by an imperative to maximize distinctiveness between words for the perceptual dimension of nasality.

On articulatory bases, Majors (1998) notes that unstressed vowels undergo more vowel-to-vowel coarticulation than stressed ones, and she hypothesizes that patterns in which unstressed vowels assimilate to stressed ones have roots in coarticulation. Other research suggesting that some or all patterns of vowel harmony have origins in coarticulation includes Boyce (1988), Ohala (1994b), Steriade (1994), Manuel (1999), Beddor *et al.* (2001, 2002), Kaun (2004), and Linebaugh (2007). Boersma (1998, 2003) suggests that certain patterns of nasal harmony have an articulatory basis; in particular, they minimize the number of velum lowering and raising gestures.²³

These issues surrounding hypothesized phonetic underpinnings and origins for harmony have been reflected with varying degrees of directness in the statement of harmony-related constraints. Versions of harmony-driving constraints have been proposed that express a restriction specifically over perceptually weak elements (e.g. Kaun 1995, 2004; Ringen and Vago 1998; Walker 2001b, 2005). Sanders' contrast-based analysis of nasal harmony utilizes constraints that explicitly require word pairs to have a certain degree of perceptual distance, which harmony reinforces. Boersma's functional analysis is implemented using constraints that penalize each movement of a particular articulator, such as the velum. Substantive considerations

have also given rise to position-sensitive constraints that may work in concert with other constraints to produce harmony patterns. Stressed syllables' resistance to change has been attributed to faithfulness constraints specific to prominent positions (Beckman 1998 [1999]). In addition, stressed syllables or other prominent positions are proposed to be the locus of markedness-based licensing, that is, a requirement that features have an association to a stressed position (e.g. Majors 1998; Walker 2004, 2005).

3.3.1.3 Attested Patterns and Constraints Another area of recent attention involves improving the harmony-driving constraint's closeness-of-fit with attested patterns. As discussed by Wilson (2002) and McCarthy (2004), problematic predictions regarding over- and undergeneration of patterns emerge with the primary formulations of the harmony imperative (e.g. ALIGN, SPREAD, *F, AGREE). A problem for AGREE is that it fails to capture harmony in forms which show partial harmony (e.g. because of blocking). It predicts instead that unless harmony is total, assimilation will fail altogether (see also McCarthy 2003b). Feature-driven markedness presents a similar problem.²⁴ Among the faulty predictions of ALIGN or SPREAD are the potential to (better) satisfy the harmony constraint by blocking epenthesis or deleting segments that are inaccessible to spreading because of blocking. Further, in the context of examining formal limits on possible constraints, McCarthy (2003b) challenges the gradient assessment of violations assumed for ALIGN and SPREAD constraints.

These issues have led to new proposals for the statement of the harmony imperative and/or the representations over which it operates. McCarthy (2004) proposes that harmony operates over *feature spans*. This approach circumvents problems of deletion or blocking of epenthesis because harmony is driven by avoidance of adjacent spans rather than a constraint that drives maximal spreading. Further, blocking segments initiate their own feature span, so segments intervening between a blocker and potential trigger can be compelled to undergo harmony as opposed to creating an independent span. A different solution to these issues is put forward by Wilson (2002, 2006c). He proposes to characterize the spreading constraint as *targeted*, which entails that the constraint identify both a marked structure and a repair.

Blumenfeld (2006) offers another take on certain harmony-driving constraints. A drawback has been noted for foot-bounded AGREE or markedness-based stressed-syllable licensing, applicable to patterns where a stressed vowel harmonizes with an unstressed one (e.g. Lena, Section 2.4.3). They make the unwanted prediction that the stress could shift to the unstressed syllable as a means of satisfying the constraint (Walker 2005; Blumenfeld 2006). To address this problem, Blumenfeld proposes *procedural* constraints, whose violation profiles are computed differently from standard constraints in OT in order to rule out certain processes. Procedural constraints are stated as implications, e.g. for foot-bounded AGREE, "if V_1 and V_2 are in the same foot, then they have the same value for [F]." A novel aspect of procedural constraints is that they cannot force the property in their antecedent to change. Thus, satisfaction of AGREE cannot be enforced by relocating foot boundaries, which could cause a shift in stress. The determination of where foot

boundaries would be located if AGREE were not present requires reference to the ranking of other constraints in the grammar.

Research on harmony imperatives thus has the potential to produce pivotal consequences for phonology theory. Proposals like those made by Wilson and Blumenfeld involve substantial departures from traditional constraint architecture in OT (Prince and Smolensky 2004). Further examination of the surrounding issues is needed to assess implications both for the analysis of harmony systems and the theory at large.

3.3.2 Feature Classes As mentioned in Section 2, some harmonies involve assimilation for more than one feature. Sets of features that pattern together frequently in phonological phenomena are referred to as feature classes, and they have spurred proposals to capture the recurrent co-patterning of particular feature clusters across languages. A significant approach is *feature geometry*, in which features are organized in a hierarchical structure in the segment (e.g. Clements 1985; Sagey 1986 [1991]; McCarthy 1988; Clements and Hume 1995, and many others). Nodes in the representation group features to form classes. For example, assimilations involving a feature class composed of [back] and [round] would involve spreading of the node that dominates these two features (e.g. Odden 1991), thereby characterizing combined back and round harmony as a unitary phenomenon.

However, the class node solution has limitations. Padgett (2002) points out that [back] and [round], which belong to a class he calls “color,” show *partial class behavior* in Turkish vowel harmony. Whereas backness harmony targets all vowels, round harmony targets only high vowels. Thus, the Turkish genitive suffix /-lEr/, with a high vowel, has four alternants combining all rounding/backness combinations [-in -yn -un -un], but the plural suffix /-lEr/ has only two alternants, front and back [-ler -lar], with vowels that are consistently unrounded. However, the class node approach predicts that either both [back] and [round] will spread or neither will spread in any given instance. Padgett dispenses with class nodes in the feature geometry and proposes a set-based notion of feature classes. For example, the set “Color” consists of the features [back] and [round], the set “Height” consists of [low] and [high], and so on. The sets, Color, Height, and so on, can be included in the statement of constraints or rules. Using this conception, Padgett employs constraint violability in OT to obtain partial class behavior. A constraint that requires spreading of Color features is dominated by a feature co-occurrence constraint *[+round, -high], as shown in (44) for the Turkish word [pul-lar] ‘stamp’ NOM-PL.

(44)

/pul-lEr/	*[+round, -high]	SPREAD(Color)
a. pullar		*
b. pullor	*!	
c. puller		**!

Violations for SPREAD(Color) are shown for each feature in the Color set that fails to spread from the root. The winning candidate, (44a), shows harmony for [back] only, respecting the higher-ranked constraint against round non-high vowels. Candidate (44b) is ruled out by the dominating markedness constraint. Candidate (44c) shows harmony for neither [back] nor [round], incurring two violations of SPREAD(Color). A root-specific faithfulness constraint is assumed to protect round, non-high vowels that originate in the root. In the genitive singular form [pul-un], [round] may also spread, because it will not cause a violation of *[+round, -high].

In addition to handling partial class behavior, an advantage of the feature set approach is its ability to characterize feature classes that partially overlap with one another, because it is not constrained by geometry. For example, as mentioned in Section 2.4.2, round harmony occurs together with backness harmony in a number of languages and with tongue root (or pharyngeal) harmony in several others. This could be handled by postulating a Color feature class and a separate class composed of [round] and [RTR]. Standard models of feature geometry would not permit [round] to be organized under two class nodes with partially overlapping features. As a result, a geometric approach would unify only one of these paired harmonies.

A related issue in the topic of feature classes concerns reaching consensus on the features involved in a particular harmony system. For example, Odden (1991) argues that height harmony in Kimatuumbi (Bantu) involves assimilation for [ATR] and [high] features,²⁵ which he postulates form a class. Yet, different analyses without involving [ATR] have posited multiple occurrences of the same vowel height feature, corresponding to differences along an acoustic scale for F1 (Parkinson 1996) or hierarchically organized aperture features (Clements 1991).²⁶

The vowel height models of Clements (1991) and Parkinson (1996) have also been applied to partial or stepwise height harmony systems. A different approach is proposed by Kirchner (1996), who employs a local conjunction (Smolensky 1993, 1997) of faithfulness constraints for the relevant harmonizing features. For example, as discussed in Section 2.4.3, Lena's height harmony causes the following raising effects /a/ → [e] and /e o/ → [i u]. At issue is preventing the raising of /a/ to [i]. Applying Kirchner's approach, the harmony-driving constraint would be dominated by a conjunction of the constraints IDENT-IO(high) and IDENT-IO(low). The conjunction is violated by any vowel that violates both of these constraints at once but not by vowels that violate only one of these constraints or that violate neither. The attested stepwise raising effects in Lena each involve violations of only one of the height faithfulness constraints. However, the unattested two-step raising of /a/ to [i] would violate the local conjunction, and is thus prevented.

In sum, OT has shed new light on certain aspects of harmonies that involve assimilation for clusters of features. The notion of constraint violability paired with a reduction in the complexity of feature geometry makes available the treatment of partial class behavior. Further, the additive effect of constraints through local conjunction finds utility in capturing partial assimilations. At the same time, debate persists on the precise set of features in some cases.

3.3.3 Blocking An important development in the treatment of blocking is the use of markedness constraints or well-formedness conditions. The insight is that a segment may block harmony when a marked segment would have resulted if it underwent harmony. Also significant is the increased emphasis on phonetic bases for segments' failure to participate in harmony. These issues received attention in Archangeli and Pulleyblank's (1994) Grounding Theory and have remained a focus of much work since.

In vowel harmony, ubiquitous cases of markedness-based blocking involve avoidance of high [-ATR] vowels and low [+ATR] vowels. For instance, as discussed in Section 2.4.4, in Pulaar, high vowels [i u] block [-ATR] assimilation and low [a] blocks [+ATR] assimilation. This has been analyzed using feature co-occurrence constraints *[+high, -ATR] and *[+low, +ATR] (for example, Krämer 2003; foundational work includes Calabrese 1988 and Archangeli and Pulleyblank 1994). In optimality-theoretic analyses, markedness constraints responsible for blocking dominate the harmony-driving constraint so that they may prevent its complete satisfaction. In Pulaar, the ranking *[+low, +ATR], *[+high, -ATR] >> ALIGN-L([ATR], word) will select fully faithful [ˈgɔra:gu] 'courage', with blocking of regressive [+ATR] assimilation by [a]. The markedness constraints rule out fully harmonic alternatives, that is, *[ˈgoræ:gu], where the low vowel becomes [+ATR], and *[ˈgɔra:gu], where the high vowel becomes [-ATR] through progressive assimilation. Similarly, the markedness constraint *[+round, -high] has been employed for blocking of round harmony by non-high vowels (for example, Kirchner 1993; Kaun 1995) and blocking by round vowels in harmony for [-high] (Beckman 1997).

Parallel approaches are seen in the analysis of vowel-consonant harmony. Working in a rule-based framework, Davis (1995a) analyzes blocking of emphasis harmony by high front vowels using grounded path conditions, RTR/HI: If [RTR] then not [+high] and RTR/FR: If [RTR] then not [-back]. The former is roughly equivalent to the constraint *[+high, -ATR]. In some emphasis harmonies, blocking effects differ according to the direction of assimilation, as discussed in Section 4.1.

Blocking in nasal vowel-consonant harmony has been analyzed using nasal feature co-occurrence constraints. Walker (1998 [2000]) proposes a hierarchy of such constraints ranked according to the compatibility of [+nasal] with other features, with lowest compatibility ranked highest. Walker bases compatibility on factors of perception, articulation, and aerodynamics. Her analysis of Applecross Scottish Gaelic (see data in Section 2.2.1) is shown in (45), with the word k^hɔ̃ʃpaxk 'wasp'. A rightward nasal spreading constraint dominates constraints that prohibit the co-occurrence of [+nasal] with fricatives, liquids, glides, vowels, and sonorant stops. (Walker's ranking and labels for these constraints are shown here.) A constraint prohibiting the co-occurrence of [+nasal] with obstruent stops is ranked over the spreading constraint, causing stops to block nasal harmony, as in candidate (45a). Candidate (45b), in which nasal harmony also spreads to obstruent stops, is prevented by the blocking constraint *NASOBSSTOP.

(45)

/k ^h ɪspaxk/	*NAS ObsSTOP	SPREAD-R ([+nas], word)	*NAS FRICATIVE	*NAS LIQUID	*NAS GLIDE	*NAS VOWEL	*NAS SONSTOP
ᵛᵛ a. k ^h ɪspaxk		****	*			**	
b. k ^h ɪspāxk̄	*!*		**			***	

Walker analyzes cross-linguistic differences in blocking of nasal harmony as the effect of ranking the spreading constraint at different points in the nasal co-occurrence constraint hierarchy.²⁷ For example, for Capanahua, which nasalizes vowels and glides but not liquids or obstruents (see Section 2.2.1), the spreading constraint would be ranked between *NASLIQUID and *NASGLIDE.

Contrast as a basis for blocking in harmony is emphasized in analyses of nasal harmony by Homer (1998) and Flemming (2004). In these accounts, nasal harmony is blocked when its occurrence would endanger or neutralize a perceptual contrast between nasal stops and certain other consonants in the language, as enforced by systemic constraints that explicitly require contrasts and that contrasts be perceptually distinct. A core idea is that contrast-centered constraints can stand in conflict with the constraint that drives nasal harmony. For example, Flemming proposes that flaps block nasal harmony in Johore Malay, while glides and vowels undergo it, because a nasalized flap [ɾ̃] is closer perceptually to a nasal stop than a nasalized glide or vowel. Since the weak contrast between the second consonant in hypothetical words [mānā] and [māɾā] is not tolerated in the language, harmony terminates when it reaches a flap, yielding [māra]. Likewise, the blocking of retroflex harmony in Sanskrit by oral dental consonants (see Section 2.2.3) is attributed to contrast maintenance (Ní Chiosáin and Padgett 1997). In some OT approaches, faithfulness constraints carry the full responsibility of preserving contrast. Thus, related insights are captured by analyses that achieve blocking using faithfulness constraints for features in a given segment type. Proposals along these lines are made by Piggott (2003) for non-participant segments in nasal harmony and by Gafos (1996 [1999]) for certain blocking effects in Sanskrit's retroflex harmony.

Contrast has also played a prominent part in analyses couched in frameworks that are not purely constraint-driven. An approach with long-standing roots builds on the hypothesis that correlations exist between contrast, markedness, and feature underspecification. This analysis employs a system of contrast-sensitive feature specification, which, in the case of harmony phenomena, obtains the presence of features that block spreading or the absence of relevant structure in transparent segments (see Dresher, Piggott, and Rice 1994 for an overview of theories in which contrast affects feature specifications). A different proposal, assuming full specification, is put forward by Calabrese (1995), who permits certain rules and conditions to be sensitive to contrastive feature specifications only.

Nevertheless, analyses relying on contrast or markedness conditions cannot readily explain cases in which blockers undergo harmony. One case was mentioned in Section 2.2.2 with respect to Jordanian Arabic. High vowels which are themselves

affected by emphasis harmony still block harmony. Similarly, in Karajá, high [-ATR] vowels undergo regressive vowel harmony and become [+ATR] but block further spreading (Ribeiro 2003), e.g. *kɔɖu-dĩ* → [*kɔɖuni*] ‘a type of turtle’ *[*kɔɖuni*]. If the trigger is a mid vowel, blocking is optional. This case appears to require a distinction between underlying high vowels which trigger harmony and derived high vowels which act as blockers. Further research is needed on this issue.

Although the usual scenario in vowel harmony is for consonants to be transparent (see Section 3.3.4 for various viewpoints on this issue), there are nevertheless reported cases of consonants blocking harmony and/or initiating their own harmonic domain. The reverse scenario, in which vowels block consonant harmony is not attested; recall that lack of blocking effects of any kind is one of the motivations for an analysis of consonant harmony that does not employ feature spreading. In Turkish, palatalized/palatal consonants [*ʃ ɟ ʎ*] condition front vowels to their right: e.g. [*usulʃ-y*] ‘method’ ACC **usul-u* (Levi 2001). In models such as feature geometry or element phonology, this is explained by assuming that palatalized consonants have vocalic features, and interact with vowel-feature spreading. A similar assumption can be applied to glides in languages such as Bashkir (Turkic) (Poppe 1964; van der Hulst and van de Weijer 1995), although the behavior of glides appears to be language-specific. For example, in Turkish, glides do not block, and Levi (2001) argues for a non-vocalic representation of Turkish /*j*/.²⁸ Cases in which consonants participate in vowel harmony are problematic for syllable-based analyses of harmony, and appear to favor local segment-to-segment-based harmony.

Other types of cases of consonants affecting vowel harmony are attested. In Assamese (Indo-Aryan) (Mahanta 2007), nasal stops block regressive ATR vowel harmony. Paster (2004) discusses the case of Buchan Scots height harmony, which is blocked by intervening voiced obstruents or nasal-obstruent clusters. In some dialects of Italy, such as the dialect of Umbertide, vowel harmony among post-tonic vowels operates across liquids but not other consonants (Canalis 2009). In Nawuri (Kwa) (Casali 1995), labial consonants (not /*w*/) block rounding harmony, and in Warlpiri (Pama-Nyungan) (Nash 1979; van der Hulst and Smith 1985; Harvey and Baker 2005), labial consonants /*p w*/ block harmony that changes /*u*/ to [*i*]. Harvey and Baker (2005) assume that spreading applies locally to consonants as well, and that [-round] is blocked from associating to labial consonants; harmony is thus halted. In other round vowel harmony systems, labial consonants do not block, suggesting that a parameterization or constraint-ranking difference must be involved. All of these cases raise the issue of how “transparent” consonants really are, and which consonants have the potential to block, and for what reason. For example, labials are assumed to share features with round vowels, but blocking by labials does not occur in all round harmonies.

Finally, the number of consonants – or their prosodic position – rather than the consonants’ quality can affect blocking. Codas block ATR vowel harmony in Lango (Nilotic) (Noonan 1992; Archangeli and Pulleyblank 1994)²⁹ and Assamese (Mahanta 2007). In Yucatec Maya (Mayan) (Krämer 2001), complete vowel copy is blocked by two consonants: e.g. [*lub'-uk*] ‘fall’ SUBJ. or [*wen-ek*] ‘sleep’ SUBJ. vs. [*hèekn-ak*] ‘break’ SUBJ **[hèekn-ek]*. These cases are all analyzed as spreading

operating between vocalic morae. Locality is violated by skipping over a consonantal mora, and blocking results.

In vowel harmony systems, blocking is also seen to arise through identity effects. A well-established identity effect is seen in some patterns of round harmony, where assimilation is restricted to vowels of the same height, as in Halh (see Section 2.4.2). Identity conditions like these are known as *parasitic* harmony systems in the work of Cole and Trigo (1988). They propose a geometric explanation in which the trigger and target are required to share a particular contextual feature. Harmony is then restricted to the domain of the contextual feature.³⁰ This basic strategy for obtaining identity effects is also implemented by Cole and Kisseberth (1995b, c) in their analyses of harmony based on *feature domain* representations.

An insightful innovation on this topic has brought articulatory explanation to bear. For round harmony, Kaun (2004: 105) suggests that the height identity condition “reflects a phonetic imperative to avoid the need for articulatory adjustments in the execution of a single gesture.” She proposes a *gestural uniformity* constraint for [round] that requires a multiply-linked [round] feature to have a uniform mechanism for its execution. This constraint will be violated when [round] is linked to vowels of different height, because a lip-rounding gesture is generally different in high versus non-high vowels (see also Kaun 1995).

Also related to articulation, Kaun (1995) has argued that a lower jaw position is antagonistic to lip rounding, giving rise to a constraint that penalizes round non-high vowels. This has been applied to round-parasitic height harmony restrictions that avoid generating non-high round vowels, for example, [o]. As discussed in Section 2.4.3, Kisa’s height harmony causes /i/ to lower to [e] following a syllable with mid [e] or [o]. However, /u/ lowers to mid only following [o], that is, /o . . . u/ sequences become [o . . . o] but /e . . . u/ sequences remain unchanged. In her analysis of this pattern in the Bantu language, Shona, Beckman (1997) uses (the equivalent of) *[+round, –high] to cause blocking of [–high] harmony by /u/. However, [–high] harmony from [o] *can* produce lowering of /u/ to [o]. In Beckman’s account, this is permitted because she postulates that both [+round] and [–high] are linked across [o . . . o] and she interprets the shared specifications as incurring a single violation with respect to *[+round, –high] (see discussion of feature-driven markedness in Section 3.3.1). A violation of *[+round, –high] will already exist for the trigger [o], so spreading in this sequence in particular will not produce additional violations. This could be conceptualized in gestural terms by reinterpreting *[+round, –high] as a constraint that penalizes the execution of lip rounding with a relatively low jaw position, without sensitivity to the dimension of its temporal extent. In other words, it is the articulatory configuration that is dispreferred without a difference in penalty for articulations of longer duration.

We note that while identity effects in vowel harmony are reminiscent of similarity conditions in consonant harmony (see Section 3.2), the hypothesized functional bases are distinct and the analyses have followed different paths in current theory.

In sum, blocking is a property of vowel harmony and vowel-consonant harmony and is generally attributed to markedness or contrast constraints on feature co-occurrence, or identity effects on the harmony system. Blocking of vowel harmony

by consonants is not common, and when it does occur can often be attributed to featural similarity between the vowel and consonant.

3.3.4 Transparency As with consonant harmony, transparency effects in vowel harmony and local vowel-consonant harmony is an area that has propelled new theoretical advances. Progress has been made both by research bringing new perspectives to already established data and by studies collecting new data observations.

A significant step forward came with a re-examination of what it means for a segment to be transparent. Various work has coalesced in support of a claim that some harmonies show *perceptual transparency* in which the assimilating property is actually present during so-called transparent segments, but without being perceived by listeners. The important consequence of this discovery is that it obviates the need to postulate skipping of transparent segments in these cases.

Instances where perceptual transparency is suggested are diverse. In the case of vowel harmony, Ní Chiosáin and Padgett (2001) argue that reported transparent consonants actually participate in the assimilation (see also Gafos 1996 [1999]). They claim that consonants may be perceived as transparent because the harmonizing feature has a low contrast potential in these segments. Further, experimental research on the articulation of reported transparent vowels in vowel harmonies of particular languages points to the harmonizing property being present during the vowel in question, although the effect might be sub-phonemic and not perceived by listeners (e.g. on Hungarian, Benus *et al.* 2004, Gafos and Benus 2006; Benus and Gafos 2007; on Kinande, Gick *et al.* 2006).³¹ A similar analysis could be applied to the transparent non-low vowels in emphasis harmony (uvularization), as discussed by Shahin (2002). She analyzes these cases as phonological transparency (skipping of the vowel), as there is no steady-state lowered F2 in tokens with transparent vowels. Nevertheless, the vowels do exhibit F2 lowering at onset followed by a rise, unlike non-low vowels in non-emphatic contexts. Whether this is simply coarticulation or is enough to qualify as [RTR] extension through the vowel is not clear. Walker and Pullum (1999) suggest that glottal stops that are reported to be transparent in nasal harmony are actually participants. They point out that the velum is presumably lowered during glottal stops in these contexts, which they take to meet the criterion of being [+nasal]. However, the glottal closure prevents nasal airflow, resulting in the lack of a nasal percept (for discussion of surrounding issues see Cohn 1990, 1993b; Ní Chiosáin and Padgett 1997; Boersma 2003).

Retroflex harmonies in Kinyarwanda and Sanskrit are other cases of this type. As mentioned in Section 2.2.3, the harmonizing tip-blade feature or gesture is hypothesized to be present during reported transparent consonants and vowels, but without significant perceptual or contrastive results (Flemming 1995; Gafos 1996 [1999]; Ní Chiosáin and Padgett 1997; Hansson 2001b, 2010; Rose and Walker 2004; Walker and Mpiranya 2006). Indeed, evidence that the harmonizing gesture is present during non-coronal consonants that had previously been reported as transparent was found for Kinyarwanda (Walker *et al.* 2008).

Further arguments for consonants' participation in vowel harmony come from patterns in which a set of consonants are transparent and a different set act as blockers. Some examples where consonants block vowel harmony are discussed in Section 3.3.3. We consider here the Najdi dialect of Bedouin Arabic (Abboud 1979), discussed by McCarthy (1994a) and Gafos and Lombardi (1999). In non-final open syllables, short /a/ raises to a high vowel, as shown in (46a). However, /a/ does not raise when it is preceded by a guttural consonant or is followed by a sequence of a guttural consonant plus [a] (but not [u] or [i]) (46b). McCarthy attributes the non-raising to sharing of [pharyngeal] across the vowel(s) and guttural. Raising also does not occur when the /a/ is followed by an oral coronal sonorant plus [a] (46c). Like the guttural cases, this is analyzed as the vowel sharing a [pharyngeal] feature with the following /a/ and the intervening consonant.

(46) a.	/katab/	[k _i t _a b]	'he wrote'
	/nataf+aw/	[nt _i faw]	'they (M) pulled feather'
	/kasar/	[k _i sar]	'he broke'
	/sakan/	[s _i kan]	'he dwelled'
	/ʃamal+uh/	[ʃm _i luh]	'his camel'
	/samiʃ/	[s _i miʃ]	'he heard'
	/ʃarib/	[ʃ _i rib]	'he drank'
b.		[ʃa _r rif]	'he knew'
		[ka _r dar]	'he betrayed'
		[saʔal]	'he asked'
		[daʒal]	'he entered'
	cf. /ʒadaʃ-uh/	[ʒd _i ʃuh]	'he deceived him'
c.		[ʒa _s al]	'he sat'
		[ʒa _r af]	'he washed away'
		[ʃa _n ag]	'he beheaded'

The claim that the feature which causes the vowel to remain low is actually present in an intervening consonant is supported by the blocking of [pharyngeal] sharing by non-guttural obstruents in the first four examples in (46a). If these consonants are unable to undergo [pharyngeal] assimilation, as McCarthy suggests, raising should take place. On the treatment of coronal sonorants' receptiveness to participating in the harmony, see McCarthy (1994a) and Gafos and Lombardi (1999). Particularly relevant to our present concern is that the pattern points to a conclusion that "transparent" consonants participate in feature sharing/assimilation between vowels and that consonants block when they do not participate.

Despite many instances of purported skipping of segments being reduced to perceptual transparency in vowel harmony or local vowel-consonant harmony, the status of other cases remains to be investigated, and a residue exists for which this explanation does not appear promising. An example of the latter is transparent voiceless obstruents in nasal vowel-consonant harmony, for example, in Tuyuca (Section 2.2.1) and Guaraní (Tupí). An acoustic study of Guaraní's voiceless stops in nasal harmony contexts confirms that they are produced as voiceless and appear

to be oral (Walker 1999). Lena's height harmony presents another case. As described in Section 2.4.3, high inflectional vowels cause raising of preceding stressed /e a o/ to [i e u], respectively. In words with antepenultimate stress, a vowel in the penultimate syllable is transparent to harmony between the final and stressed vowels, as in (47) (Hualde 1989a).

- (47) a. trw'ebanos trw'ibanu 'beehive' (M PL./M SG.)
 b. p'aɟara p'eɟaru 'bird' (F SG./M SG.)

Although this phenomenon awaits instrumental investigation, it appears likely that unstressed /a/ genuinely does not undergo the height harmony (Walker 2004). It is improbable that harmony-induced raising of unstressed /a/ to [e] is not perceived, as [e] is an attested unstressed vowel quality in Lena.

The resulting theoretical picture is one in which transparency effects are represented in more than one way correlating with (at least) two types of distinct phenomena. In cases of perceptual transparency, segments actually undergo harmony, that is, they become specified for the harmonizing feature. In other patterns, transparent segments genuinely do not present the harmonizing feature. In many of cases of *genuine transparency*, the transparent segment could be prevented from presenting the harmonizing feature because of a phonetically-based markedness constraint. This seems tenable, for instance, in the case of transparent voiceless obstruents in nasal harmony, but seems less probable for Lena.

Harmony patterns that show genuine transparency have sparked numerous proposals, and apart from widespread agreement that these segments do not bear the harmonizing feature or gesture, there is little consensus on the particulars of their analysis. We examine some of the major concepts here.

Several proposals have emerged that preserve the claim that feature spreading may not skip segments. Several of these postulate separate but identical occurrences of the harmonizing feature specification before and after a transparent segment, as illustrated in (48), rather than a gapped feature linkage.

- (48) • • •
 | | |
 +F -F +F

For example, in work on vowel harmony, Pulleyblank (1996) interprets violations of feature alignment in terms of what he calls *local domains*, which can drive identical feature specifications to flank a transparent segment. Nevins (2004) formalizes harmony as a feature copy procedure which searches out targets according to specific parameters. Walker (2004) proposes that stress-targeted harmonies (e.g. in Lena) operate over feature *chains*, which permits harmony to be achieved by a corresponding feature specification in a target syllable. Krämer (2003) characterizes transparency as *balance*, where a transparent vowel is required to either agree for the harmonizing feature with the vowels in both of its flanking syllables

or to disagree with both. Baković (2000) and Baković and Wilson (2000) use a targeted markedness constraint that disfavors forms in which certain segments undergo harmony. This constraint imposes a harmonic ordering on certain candidate pairs and interacts with AGREE to yield transparency.

In the area of nasal harmony, Sanders (2003) proposes that harmony in Tuyuca is driven by constraints on contrast, not spreading. Constraints on perceptual distinctness are better satisfied the more two words differ in nasality. However, a highly ranked markedness constraint on nasalized voiceless obstruents prevents these segments from being formed, at the cost of maximizing contrast; otherwise all segments in the word agree in nasality. Walker (1998 [2000]) analyzes transparency in nasal harmony as a kind of derivational opacity implemented in OT using sympathy theory (McCarthy 1999b). Her account builds on rule-based scenarios where a transparent segment undergoes spreading for the harmonizing feature, with the segment's harmonizing feature specification being subsequently altered, as driven, for example, by a markedness constraint (e.g. Clements 1980; Vago 1976; Piggott 1988b).

The above analyses prevent the need for gapped configurations, which permits more concrete representations where interruptions in an articulatory posture for a transparent segment are directly reflected in features' domains of association (or in gestures' extent of duration). However, other approaches allow gapped configurations or something similar. As mentioned in Section 3.1.2, gapping across intervening segments is a traditional approach to transparency in autosegmental spreading accounts. Some recent analyses of vowel harmony that employ this strategy, with locality defined other than by strict root adjacency, include Halle, Vaux, and Wolfe (2000), Uffmann (2004), and Calabrese (2005). See also Shahin (2002). Boersma (2003) proposes that transparent segments in nasal harmony in languages like Tuyuca cause violations of the Line Crossing Constraint, a structure that he couches in the context of the perceptual representations that he posits. In work making use of feature-based domains, the domain of a feature specification spans a continuous sequence of segments but it may fail to be realized on certain segments within its domain, in order to satisfy a higher-ranked constraint (Smolensky 1993; Cole and Kisseberth 1995a, b, c).

In sum, work tackling transparency has yielded new and recent discoveries, including experimental evidence that certain transparent segments are participants in harmony to some degree. Overall, while progress has been made on the analysis of vowel harmony and local vowel-consonant harmony, certain issues surrounding the harmony imperative, feature classes, blocking, and transparency all continue to be the topic of active investigation and debate.

3.4 *Analyses of Non-local Vowel-consonant Harmony*

Non-local vowel-consonant harmony poses problems for both autosegmental spreading and analyses that do not specify targets. There could be an expectation that they should display the same properties as local vowel-consonant harmonies, but in fact they do not. The transparent intervening segments that are responsible

for the non-local property do not fall neatly into the typology of transparent segments just identified. Due perhaps to the typological rarity of non-local vowel-consonant harmony, but also to the idiosyncrasies of these systems, no unified analysis has been forthcoming.

In Salish retraction, harmony from faucal consonants targets vowels, but skips consonants. Bessell (1998) assessed whether long-distance anticipatory coarticulation could have given rise to faucal harmony. However, coronals would then be expected to show some evidence of participation, as they have an antagonistic articulation with tongue root retraction and retracted pronunciations of coronals have been recorded in related languages with local coarticulation, such as Nxaʔ mxcin. Instead, Bessell suggests that Salish non-local harmony arose from the strong compatibility of [RTR] with vowels, and its marked combination with consonants.

In Sibe and Harari, features associated with vowels target consonants, but skip certain intervening vowels and consonants. Recall that in Sibe, a velar consonant in a suffix becomes uvular if there is a preceding non-high vowel in the root. Li (1996: 307) proposes an analysis of Sibe whereby a redundant secondary vowel feature (A^2 in dependency phonology, equivalent to [RTR]) is spread from the non-high vowel to the consonant. Intervening high vowels, which are transparent, have primary vowel features, and are invisible to spreading by secondary features due to tier-based segregation. Nevins (2004) and Nevins and Vaux (2004b) present a different analysis of Sibe in which the feature [-high] spreads from non-high vowels to a suffix velar consonant. Since both [+ATR] and [-ATR] vowels can trigger the harmony, they argue that a height feature is responsible rather than a tongue root feature. Li (1996) notes that there is no [ATR]/[RTR] contrast for vowels in Sibe. Nevins and Vaux analyze transparency using contrastive visibility (Calabrese 2005) in which high vowels are unmarked and non-high vowels are marked in Sibe. The harmony rule specifies that only the marked value of the harmonic feature is “visible,” namely [-high]. This analysis requires a specific target and theory of markedness-based spreading which calls into question other accounts of transparent segments. It remains to be seen how applicable this approach could be to other cases of non-local interaction.

In Harari, palatalization affects alveolar consonants at a distance from the trigger vowel, skipping over all non-targets including palato-alveolars and high and front vowels. If feature spreading were the mechanism by which harmony were achieved, blocking by segments specified for the spreading feature such as these would be expected. Rose (2004) proposes a correspondence-based agreement requirement between suffix and stem, and further parameterizes it to refer to specific targets: obstruents are favored over sonorants. Not using spreading avoids transparency problems, but the trigger and target are specifically singled out.

While local vowel-consonant analyses converge on spreading or extension of features/gestures, with attendant predicted blocking and transparency effects, there appears to be no unified analysis of non-local vowel-consonant harmony. The cases are sporadic and each presents unique properties. All of them probably developed in some manner from local coarticulations or assimilations that have become extended and/or morphologized.

4 Further Aspects of Harmony Systems

4.1 Directionality

Harmony can operate in a leftward (regressive) or rightward (progressive) direction, or bidirectionally. While many analyses incorporate directionality into rules or constraints, directionality has been argued to follow from morphological structure (Baković 2000; 2003). There have also been proposals of directionality bias, suggesting that the default direction for vowel harmony and consonant harmony is regressive (Hyman 2002; Hansson 2001a, b, 2010 respectively), connecting this to speech planning or other functional explanations.

In Yoruba, tongue root harmony is regressive from roots to prefixes (Archangeli and Pulleyblank 1989).

- (49) a. O + gE + de [ogede] 'incantation'
 b. O + gE + dɛ [ɔgedɛ] 'banana, plantain'

As mentioned in Section 3.3.1, in OT, a widespread approach to harmony uses directional alignment constraints (Kirchner 1993), which align the harmonic feature with edges of morphological domains, such as roots or words, or prosodic domains, such as feet or prosodic words. Regressive harmony in Yoruba would be expressed using ALIGN-L([RTR], WORD) (Pulleyblank 1996).

Some researchers have eschewed stipulating directionality. Clements (1981) proposed that unspecified segments trigger feature spreading from a specified segment due to a well-formedness requirement. In the Yoruba example above, spreading is automatically regressive to fill in [ATR] specifications on the prefixes. Other researchers have achieved directional effects through positional faithfulness (e.g. Kaun 1995; Beckman 1997; Walker 2001b), by requiring that strong positions (root-initial, stressed) preserve their features. Baković (2000, 2003) argues that the morphological affiliation of the segments is responsible, and that harmony is stem-controlled, operating from the root outwards to affixes. Yoruba only appears to have regressive harmony because it is a prefixing-only language. In a suffixing-only language like Tangale (Chadic) (Kidida 1985), harmony is progressive. In a language that combines prefixes and suffixes such as Akan (Tano) (Schachter and Fromkin 1968; Clements 1981), harmony is bidirectional. Stem-controlled harmony is expressed as a cyclic system, operating in successively larger domains. This is expressed formally by a faithfulness constraint STEM-AFFIXED FORM IDENTITY (SA-IDENT), requiring a stem in an affixed form to be identical to the unaffixed stem for a given feature.

In dominant-recessive systems, however, suffixes can cause roots to harmonize, as was shown for Maasai in Section 2.4.4. Such systems are bidirectional, with harmony operating from wherever the dominant [ATR] feature is located. Dominant-recessive systems are analyzed with SA-IDENT outranked by constraints forcing harmony for the dominant feature (Baković 2000).

Dominant-recessive systems can display asymmetric directionality behavior with respect to vowels with no harmonic counterpart. In Maasai (Tucker and Mpaayei 1955), the low vowel /a/ has no [+ATR] counterpart. Such vowels may be opaque, transparent, or undergo *repairing* (Baković 2000), alternating with a vowel that is normally another vowel's counterpart. The vowel [a] occurs in [-ATR] words (50a). Progressive harmony from the root *repairs* /a/ by raising and rounding it to [o] (50b), but in regressive harmony triggered by a suffix (50c) /a/ is a blocker. It also fails to undergo harmony when a prefix (50d).

- | | | | | |
|------|----|------------------------------------|-------------|----------------------------|
| (50) | a. | /in- <u>lipɔŋ</u> -a/ | ɪlɪpɔŋa | 'full-grown female' |
| | b. | /in- <u>mudon</u> -a/ | imudonɔ | 'kinship' |
| | c. | /ɛ- <u>ɪput</u> -a-rɪ- <u>ie</u> / | ɛɪputariyie | 'it will get filled up' |
| | d. | /a- <u>duŋ</u> -akɪn- <u>ie</u> / | aduŋokinie | 'I cut for s.o. with s.t.' |

Archangeli and Pulleyblank (1994) express the directional asymmetry by imposing a grounded condition on the regressive rule, preventing the combination of [+ATR] and low: LO/ATR; there is no such condition on the progressive rule, and harmony applies to /a/.

Baković (2002) argues that directional stipulation predicts vowel harmony systems which do not occur, such as the opposite of Maasai: progressive blocking with regressive harmony.³² A stem-control analysis predicts that systems may have blocking in both directions, or only in the regressive direction, as in Maasai. His analysis appeals to SA-IDENT for the non-harmonizing features affected by repairing: [low] and [round], protecting the stem from harmony in the regressive direction. Prefixal /a/ in Maasai is predicted to harmonize with the stem, but in fact it does not (50d). This follows from a directional analysis, but the stem-control analysis must treat prefixes as outside the harmonic domain or subject to special faithfulness.

There are vowel harmony systems that show no effects of stem control. Ribeiro (2003) presents data from Karajá, a Macro-Jê language spoken in Brazil, which has both prefixes and suffixes and a regressive [+ATR] dominant harmony. Harmony is triggered by affixes and clitics (51a, b), or by roots. Examples (51c, d) show a disharmonic root /duhɔ/ in which the initial [+ATR] vowel /u/ triggers regressive harmony in prefixes. The second root vowel can become [+ATR] when followed by [+ATR] suffixes or clitics (51d).

- | | | | | |
|------|----|------------------|----------------|-----------------------------|
| (51) | a. | ∅-r-a-kɔhɔdɛ=r-e | [rakoho'dere] | 'he/she hit' |
| | b. | bɛdɔ-dī | [bedo'ni] | 'a type of <i>filhote</i> ' |
| | c. | ∅-r-ɔ-duhɔ=rɛrɪ | [rotʃu'hɔrɛrɪ] | 'he is cursing' |
| | d. | ∅-r-ɔ-duhɔ=r-e | [rotʃu'hore] | 'he cursed' |

This case presents a problem for proposals to reduce directionality to stem control, as examples such as (51c) show. The clitic /rɛrɪ/ is unaffected by harmony from the root. Similarly, Sasa (2004) argues that regressive directionality in Pulaar's ATR harmony cannot be reduced to effects of cyclicity or positional faithfulness.

Mahanta (2007) shows that Assamese also involves regressive ATR harmony and argues for a sequential markedness account, notably *[-ATR][+ATR]. Hyman (2002) speculates that a tendency for regressive directionality in vowel harmony in the absence of root control may be connected with the greater robustness of anticipatory vowel-to-vowel coarticulation. Nevertheless, cases of genuine directionality are not all regressive. Harrison (2000) finds evidence in Tuvan that backness harmony which affects epenthetic vowels is progressive in word-medial contexts (see Section 2.4.1).

Directionality in vowel-consonant and consonant harmony is not always reducible to stem control. In nasal vowel-consonant harmony, direction of spreading frequently has to be stipulated, and often occurs within roots. In Capanahua, nasal harmony is regressive, whereas in other languages with the same set of targets, such as Malay, it is progressive. Walker's (1998 [2000]) analysis of nasal harmony incorporates directionality into spreading constraints (SPREAD-R or SPREAD-L) to reflect this. Hansson (2001b, 2010) argues that cases of progressive consonant harmony can be described as stem-controlled, but regressive harmonies cannot. In Ineseño Chumash, suffixes trigger changes on roots. Hansson (2001a, b) relates the regressive bias to speech production. In speech production studies, anticipatory errors and assimilations are more common than perseverative (Dell, Burger, and Svec 1997). This is modeled in a serial-order theory of speech production in which look-ahead activation of a consonant being planned can cause an earlier segment – especially a similar one with shared activation – to anticipate its production.

Directionality may affect the extent of harmony. In Nawuri (Casali 2002; Hyman 2002), phrasal vowel harmony is unbounded in the regressive direction, but only affects a single high vowel in the progressive direction. Similarly, progressive emphasis harmony in Northern Palestinian Arabic (Davis 1995a) is limited to adjacent syllables. Furthermore, progressive emphasis harmony is subject to blocking, whereas regressive emphasis harmony is generally unrestricted. Davis (1995a) uses this to argue for “process-specific” spreading rules, a progressive rule with a grounded condition RTR/HI and RTR/FR, which prevents [RTR] combining with high or front segments, and a regressive rule with no target conditions. McCarthy (1997) instead achieves the directional effect through ranking, with directional harmony constraints: ALIGN-RTR-LEFT >> RTR/HI&FR >> ALIGN-RTR-RIGHT >> IDENT-ATR. Regressive RTR harmony is more important than respecting the markedness constraint. Watson (1999) suggests that regressive is the unmarked directionality for RTR harmony, and this is why it overrides grounded or markedness conditions. Greater restrictions are placed on the marked direction, limiting its application.

Different segments may be targets or triggers in different directions. In Kinande (Mutaka 1995; Archangeli and Pulleyblank 2002), regressive ATR vowel harmony targets all seven underlying vowels /i ɪ u ʊ ε ɔ a/. The low vowel /a/ is an undergoer or transparent (see Gick *et al.* 2006 on transparent low vowels in Kinande). In contrast, progressive harmony only operates between high vowels, and /a/ is opaque to harmony. Archangeli and Pulleyblank (2002) develop an

analysis of the directional asymmetry by utilizing only an ALIGN-L constraint. Progressive harmony follows not from ALIGN-R but from the grounded condition HI/ATR (if [+high], then [+ATR]) applying in different morphological domains.

In conclusion, recent research has put forward the hypothesis that there is a regressive directionality bias for vowel harmony, consonant harmony and some cases of vowel-consonant harmony. The source of this bias and its status in linguistic theory is still being explored. On the other hand, stem control may override the directionality bias in certain cases. This is clearly an area for future research.

4.2 *Domains*

Harmony can be delimited by its domain of application, referring to the maximal constituent to which harmony is confined. Although there was a general recognition of proximity requirements in prior work on harmony, these requirements have been formalized using phonological constituents such as syllable and foot. Perhaps the strongest recent advancement has been the development of licensing analyses of stress-based harmonic systems.

4.2.1 Phonological Domains Vowel-consonant harmony, both nasal and emphasis harmony, can be restricted to apply within the syllable. However, this can also be analyzed as basic non-continuous local assimilation, that is, not harmony according to our definition. Harmony operating between adjacent syllables (Odden 1994a) is common. In Ndonga (Bantu) (Viljoen 1973) or Lamba (Bantu) (Doke 1938), nasal consonant harmony only occurs when the target and trigger are in adjacent (open) syllables. In vowel harmony, syllable adjacency is difficult to tease apart from blocking and non-iterativity. In Kikuria (Bantu) height harmony, a high vowel causes raising of preceding mid vowels, but an intervening low vowel blocks height harmony. Although Odden (1994a) analyzes this as a case of syllable adjacency, the low vowel could be a blocker, failing to undergo and transmit harmony. Blocking is not a factor in Standard Bengali (Indo-Aryan) harmony (Mahanta 2007). High vowels /i u/ trigger [+ATR] harmony regressively to /ε ɔ/ only in the immediately preceding syllable:

(52)	pɔtro	‘letter, document’	potrika	‘horoscope’
	k ^h ɛla	‘game’	k ^h eli	‘to play’
	kɔt ^h a	‘spoken words’	kɔt ^h ito	‘uttered’
			kɔt ^h oniyo	‘speakable’
	pɔd	‘position’	pɔdobi	‘position holder’

As mentioned in Section 3.1.2, Odden (1994a) proposes that adjacency parameters (root adjacent, syllable adjacent) be added to basic considerations of locality, such that interacting segments have adjacency restrictions imposed, or are unrestricted. Uffmann (2004) recasts Odden’s adjacency parameters as optimality-theoretic constraints and Pulleyblank (2002) implements a range of proximal vs. distant

requirements on his sequential anti-disagreement markedness constraints. Kaplan (2007, 2008) has argued that some non-persistent harmony cases are due to minimal satisfaction of positional licensing requirements of harmonic features in specified positions or domains rather than adjacency constraints. For example, in Lango (Nilotic) (Noonan 1992), ATR harmony applies regressively from a suffix to the final root vowel: bɔŋɔ-nɪ → bɔŋóní ‘your dress’. Kaplan treats this as a licensing requirement whereby [+ATR] must be realized on the root; a single affiliation satisfies the constraint.

Two adjacent syllables can constitute a metrical foot, rendering the foot constituent the domain of harmony. In Kera (Pearce 2007a), regressive fronting harmony operates within an iambic foot. Central vowels are fronted only within the same foot as a trigger front vowel: e.g. bàl-é → [(bèlè:)] ‘love’ but bàad-é → [(bàa)dè] ‘wash’. In this case, it is not clear whether stress plays a role in the harmony. However, harmonies do exist that target stressed segments (e.g. metaphony and umlaut patterns), or are triggered by stressed segments, for example, Guaraní nasal vowel-consonant harmony or Old Norwegian height harmony (Majors 1998). In these cases, foot-bounded domains become an issue.

Certain metrical approaches to harmony make reference to asymmetries, for example between heads/non-heads or strong/weak elements (see Halle and Vergnaud 1981 for foundational work). Hualde (1989a) proposes a metrical account of metaphony systems, such as Lena’s harmony (Section 2.4.3, Section 3.3.4) (see also Zubizarreta 1979). Hualde’s analysis uses the metrical structure constructed for stress assignment: the assimilating feature percolates to targets within it, and the stress foot delimits the margins of harmony. As Majors (1998) points out, not all work in this tradition postulates coincidence of metrical stress feet and metrical harmony structure, which loses the advantage of utilizing existing constituents.

Similar issues arise with other foot-based analyses. Flemming (1993) argues that the harmonies in question result from autosegmental spreading rules without reference to stress. Spreading is restricted by a constraint that limits a feature’s associations to units within the same metrical foot. Piggott (1996) proposes a similar analysis for Lamba’s nasal consonant harmony in adjacent syllables as licensing of the feature by the harmonic foot. This case does not show coincidence with stress patterns, and the “foot” could simply serve as a method of achieving (often) binary groupings of syllables. Likewise, Flemming’s approach has been challenged on the basis of the foot structures it requires to obtain the harmony domain (Beckman 1998 [1999]; Majors 1998; Walker 2005).

An area of substantial growth in the last decade centers on licensing approaches to positional asymmetries, which formulate constraints in terms of position-sensitive faithfulness or markedness. Beckman (1998 [1999]) proposes stressed-syllable faithfulness constraints for nasal harmony in Guaraní, which is triggered by stressed nasal vowels and blocked by stressed syllables that contain an oral vowel. Beckman uses a faithfulness constraint for [nasal] in stressed syllables, IDENT-ó(nasal), which, together with a markedness constraint that drives harmony, captures both the triggering and blocking status of stressed syllables.

A positional markedness approach to stress sensitive harmonies is developed by Majors (1998) and Walker (2005), which emphasizes hypothesized articulatory and perceptual bases of these patterns. Their analyses employ a licensing constraint that requires a given feature specification to have an association to a stressed syllable (cf. Klein 1995). The constraint is satisfied either when the feature specification is only linked to a stressed position or is linked to both stressed and unstressed syllables, a configuration known as *indirect licensing* (Steriade 1995). Majors teams this constraint with a faithfulness constraint for stressed syllables to obtain harmony patterns where segments in unstressed syllables assimilate to stressed ones. In harmonies where a stressed vowel assimilates to an unstressed one, stressed-syllable faithfulness is dominated by another constraint that determines control by an unstressed trigger. Examples include a morpheme-specific faithfulness constraint for harmonies triggered by particular inflectional vowels (Majors 1998) or a phonological constraint that blocks formation of the vowel quality that would occur under assimilation of the unstressed vowel to the stressed vowel (Walker 2005).

4.2.2 Morphological/Morphophonological Domains A standard domain of harmony is the word, in which harmony applies across internal morpheme boundaries. The “word” may correspond to the morphological notion of word, or be described as the “phonological word,” a prosodic constituent, if clitics are included.³³ In fact, vowel harmony is often used as a diagnostic for determining word boundaries (Suomi, McQueen and Cutler 1997; Bauer 2003: 60). There are nevertheless cases in which harmony is restricted to the root or behaves differently within the root, and others in which certain affixes are non-undergoers of harmony.

Various consonant harmony patterns are confined to the root, including laryngeal, nasal, and dental harmony. Ngbaka (Adamawa-Ubangi) is cited as a root-restricted vowel harmony pattern (Archangeli and Pulleyblank 2007). In some languages, roots show disharmonic patterns while harmony applies across morpheme boundaries, as argued by Clements and Sezer (1982) for Turkish. Pulleyblank (2002) also makes a case for a root/word domain distinction based on differing patterns in the height harmony system of C’Lela (Benue-Congo) (Dettweiler 2000), in which the sequence high vowel non-high vowel is unattested in roots, but is possible spanning the root-suffix boundary.

Further cases exist where affixes or clitics may fail to harmonize. This may be due to idiosyncratic reasons or their peripheral status in the word. In Wolof (Atlantic) (Ka 1994), progressive ATR harmony changes the vowel /a/ to [ə]: *nɛlaw-əm* ‘his/her sleep’ versus *dugub-əm* ‘his/her millet’. The agentive suffix /-kat/ fails to become [+ATR] when associated to [+ATR] stems: *luxus-kat* ‘magician’ *[luxus-kət]. It can also initiate a new [-ATR] harmonic domain: *luxus-kat-am* ‘his/her magician’. The standard approach to these cases is to specify the segment/morpheme with an underlying [-ATR] specification.

In Standard Yoruba, subject clitics do not harmonize with the root. In Oyo and Ibadan Yoruba, back round subject clitics do harmonize (Akinlabi and Liberman 2000). Przewdziecki (2005) treats clitics as part of the phonological word.

(53)	Standard	Oyo/Ibadan	
	mo lɔ	mɔ lɔ	'I went'
	mo yó	mo yó	'I am fed'
	ó wá	ó wá	'he/she came'
	ó dé	ó dé	'he/she came'

The domain of vowel harmony does not always match the prosodic domains of other phonological processes, however, and may be difficult to define morphologically, as some clitics participate and some do not. Kabak and Vogel (2001) conclude that domains defined in terms of prosodic constituents such as the “phonological word” or “clitic group” do not accurately denote the domain of vowel harmony in Turkish.

In Bantu, vowel harmony typically operates within a morphological domain consisting of the verb stem minus the final vowel (Hyman 1999) and does not extend to pre-verb stem clitics. The verb stem in Bantu does not correlate exactly with a derivational/inflectional split, since it contains some inflectional morphemes. Terms such as the *macrostem* or *extended stem* have been proposed (e.g. Myers 1987 [1990]).

One method of referencing domains in OT is through morphologically indexed constraints. This is achieved by having versions of the same constraint subscripted for domains. For Kinande vowel harmony, Archangeli and Pulleyblank (2002) propose domain specific versions of H_I/ATR: H_I/ATR_{Root} >> H_I/ATR_{stem} >> H_I/ATR_{macrostem} to achieve the blocking effects in Kinande described in Section 4.1. Other constraints, such as ALIGN-L (responsible for regressive harmony) are ranked above and between them. Archangeli and Pulleyblank (2002) further argue that constraints differentiated by domain are harmonically ranked from smaller to larger domain, essentially achieving the cyclic effect of harmony operating from the root outwards.

Harmony can apply to domains larger than the word. Ka (1994) argues that vowel harmony in Wolof applies within the phonological phrase. This includes the head of the phrase (noun or verb) plus complements to the right, ex. [dugg ngə cə] ‘you went into it’ versus [dəm nga ca] ‘you went to it’ or [[goor nə dinənu ko] gas] ‘the men will dig it’ versus [[xalɛ ya dinaɲu kɔ] door] ‘the children will hit him/her’. Phonological phrases do not always correspond to syntactic structure. Harmony domains that cross word boundaries are also reported for Nawuri (Casali 2002), Somali (Cushitic) (Hall *et al.* 1974), and Vata (Kru) (Kaye 1982).

Finally, there may be optionality in whether harmony applies, and gradience in the extent of the harmony. Mutaka (1995) observes that harmony in Kinande in a phrase such as èmítí míkù:hì ‘short trees’ can affect no preceding vowels, one [èmítí míkù:hì], two [èmítí míkù:hì], or all vowels [èmítí míkù:hì]. The further away from the trigger a morpheme is, the less likely it is to harmonize. This can be viewed in more functional terms if harmony is analyzed as extension of gestures, and the ‘strength’ of the gesture fades the further it is from the original source. This would suggest that vowels are less strongly altered further away, apparently the case for Kinande (Archangeli and Pulleyblank 2002).

In summary, the role of morphological domains is generally recognized and incorporated into analyses, but there has been little debate on how the extent of harmony in terms of morphology should be addressed. In OT, the issue is addressed by indexing constraints for the domains in which they operate (Archangeli and Pulleyblank 2002).

5 Shifts in Empirical Focus

Linguistic analysis rests on an empirical foundation. Recent empirical work has shown a shift in the types of data being emphasized. Four particular categories are (i) research on lesser-studied languages, (ii) instrumental studies, (iii) studies of variation and/or statistical tendencies and (iv) psycholinguistic production tasks. Research in these directions has led to refinements in our understanding of harmonic issues and have brought about new theoretical advances.

The importance of research on lesser-studied languages is reflected in the variety of languages discussed here, and in the contribution of new data to typological generalizations and theoretical claims. As discussed in Section 4.1, certain research has pushed to make directionality effects in harmony derivative of other properties of the system. However, descriptive work of under-studied languages, such as Karajá (Ribeiro 2003) and Tuvan (Harrison 2000), has provided solid evidence to the contrary. Lacking these studies, the question of whether directionality exists as an independent characteristic of vowel harmony would be more ambiguous. Furthermore, descriptions of endangered languages can reveal illuminating changes in harmony systems. Anderson and Harrison (to appear) present a study of Tofa, a moribund Turkic language, in which vowel mergers have taken place, creating a more abstract vowel harmony system for younger speakers, as well as considerable micro-variation in round vowel harmony. Therefore, it is essential that detailed description of harmonies in languages be pursued, going beyond the well-known systems that have formed the primary emphasis of research to date.

Experimental studies of variation or statistical tendencies have been conducted for the vowel harmonies of Hungarian and Finnish. While both languages have backness harmony with harmonic and neutral vowels, closer examination of speakers' behaviors revealed subtleties not accurately captured in previous descriptions. Ringen and Kontra (1989) performed a questionnaire-based study on Hungarian that investigated suffix vowel choice with disharmonic roots (mostly loans) ending in *neutral* front vowels [i], [i:], [e], and [ɛ], which are reported to be transparent to backness harmony. They discovered that the lowest neutral vowel [ɛ] actually triggers harmony in most cases, the second lowest vowel [e] tends to be transparent but shows some variability, and the highest neutral vowels are indeed transparent. The study identified considerable vacillation in suffix vowel choice following sequences of two syllables with neutral suffix vowels. A connected study by Kontra, Ringen, and Stemberger (1991) found that sentence context influences suffix vowel choice in words that show vacillation. In more

recent research, suffix vowel choice with stems containing neutral vowels has been investigated by Hayes and Londe (2006), using a 'wug' test, where speakers selected suffix forms for novel stems. They also collected data on quantitative patterns using a web search approach (see also Wanlass 2008 for an online corpus study).

A study of Finnish by Ringen and Heinämäki (1999) also investigated suffix vowel choice with disharmonic loanwords using questionnaires. In loans, harmonic front and back vowels were reported to pattern asymmetrically, with certain normally harmonic front vowels behaving as transparent. Ringen and Heinämäki's study found that in disharmonic roots where the last vowel was back, the suffix vowel was almost always back, that is, the final vowel was a trigger. In disharmonic roots where the final vowel was front, many forms presented variation, determined by a variety of factors such as stress and vowel quality. Not only have these studies uncovered aspects of the harmony systems that were hitherto unknown, but also the statistical tendencies that they identify are problematic for standard rule-based or classic OT approaches, necessitating revisions to the theory (Ringen and Heinämäki 1999; Hayes and Londe 2006).

New research on harmony has also emerged in the field of artificial language learning and experimental production tasks, research which tests the naturalness and functional underpinnings of harmony systems. Pycha *et al.* (2003) trained naïve speakers on different patterns of non-local vowel interaction, both harmony and disharmony, and Wilson (2003) tested adults' ability to learn nasal consonant harmony or disharmony patterns in suffix choice. Both studies concluded that speakers learned the harmonic/disharmonic systems, but did not learn more "random" or complex rules. Mintz and Walker (2006) tested English-learning infants' sensitivity to vowel color harmony using the head-turn preference procedure. The infants showed an ability to segment words based on color harmony even though their ambient language environment had not previously exposed them to vowel harmony patterns. Koo and Cole (2006) tested liquid consonant harmony/disharmony versus back vowel harmony/disharmony and found that liquid (dis)harmonies were more easily learned. They concluded that this was due to the perceptual similarity involved in liquids, as highlighted in recent work on consonant harmony. Other experimental learning-based studies of harmony are reported by Finley (2008) and Zaba (2008). Research by Cole *et al.* (2002) tested speech production (production time and error rate) for nonce words in which vowels agreed on the front/back dimension versus the height dimension. They found that front/back harmony facilitated speech production but height harmony did not. Walker (2007) and Rose and King (2007) used different speech error elicitation tasks to test connections between similarity and speech production underlying the analysis of consonant harmony systems. Rose and King (2007) examined the impact of harmony constraints on speech errors, and found elevated speech error rates for sequences that violated laryngeal harmony. Walker (2007) found that the consonants that were more prone to participate in speech errors with nasals in English matched the ones preferentially targeted in nasal consonant harmony across languages.

Instrumental studies of harmony have been a critical source of new evidence on topics that have long been the subject of debate. They have been especially valuable on issues that cannot be straightforwardly resolved by ear-based transcription. Acoustic studies of faucal harmony and emphasis harmony have been conducted by Bessell (1998) and Shahin (2002), shedding new light on the properties of these tongue root systems. Articulatory studies have also proved especially revealing. A study of Kinyarwanda by Walker *et al.* (2008) used electromagnetic articulography to uncover evidence that the harmonizing retroflex posture persists during reportedly transparent non-coronal consonants when they occur between audibly harmonizing fricatives. A lingual ultrasound study of Kinande by Gick *et al.* (2006) found that /a/, reported to be transparent in the language's harmony, actually shows advanced and retracted root positions consistent with its full participation in tongue root harmony. Research on Hungarian by Benus and Gafos (2007) using electromagnetic midsagittal articulometry examined neutral front vowels. They found that the neutral vowels in monosyllabic stems that select front vowel suffixes had a significantly more advanced tongue position than ones in stems that select back vowel suffixes.³⁴ However, the difference in tongue advancement in these vowels did not alter their front perceptual quality, accounting for its failure to be reflected in transcription. The question of when a subtle but consistent degree of shift in articulation reaches the criterion for a difference in the phonological representation of segments is not uncontroversial. Thus, instrumental research can clearly contribute on various outstanding issues in harmony on a case-by-case basis. At the same time, it raises new questions for the goals of phonological analysis and how and whether observations of data involving variation along a phonetic continuum should be modeled within phonology.

Across each of the above categories of data types, much remains to be documented and discovered. Continued study in these directions will surely continue to shed new light on the topic of harmony.

6 Conclusion

This chapter has attempted to synthesize and elucidate the main contributions of recent research into harmony systems. There has been considerable progress made over the last decade in the study of harmony, but at the same time divergence of analysis. Of course, it is hard to do justice to such a vast topic in an overview chapter. Within the bounds that this paper affords, we have concentrated on certain themes and theoretical approaches, but there remain areas of research that are worthy of consideration beyond that which we can cover here. Nevertheless, we are confident that the topic of harmony is sufficiently rich that readers will be able to use this chapter as a platform to explore topics in greater detail and make their own future contributions to the study of harmony systems.

NOTES

- 1 Hansson (2001b, 2010) defines consonant harmony as operating over at least a vowel. Indeed, consonant harmonies rarely apply across a string of two or more consonants, but such cases do exist. In Imdlawn Tashlhiyt Berber (Elmedlaoui 1992), sibilant harmony can apply across strings that lack a vowel: e.g. s-bbrb → [fbrb] ‘be gaudily colored’ (underlining indicates pharyngealization).
- 2 We do not discuss consonant harmony in child language, which does involve harmony for place. See Goad (1997), Rose (2000), Pater and Werle (2001, 2003) for recent discussion.
- 3 Although Harms (1985) transcribes this form with a pre-nasalized [s], Harms (1994) has more recently indicated that [s] is not pre-nasalized after a nasal vowel.
- 4 Harms (1985) states that /s/ blocks progressive nasal spreading. The more recent description by Harms (1994: 8) seems to suggest that /s/ does not invariably block spreading, but among the data provided in that work he includes the example [mīəsu] ‘spear’, in which it serves as a blocker.
- 5 Shahin (2002) argues that St’át’imcets Salish (Lilloet) has a post-velar harmony like Arabic, but as it affects only a single adjacent segment to the left, this does not fall under our definition of harmony and would be analyzed as local assimilation.
- 6 Walker *et al.* (2008) also find evidence that points to [ɾ] undergoing harmony.
- 7 Tuvan also shows a round harmony that we do not discuss here.
- 8 Whether pharyngeal harmony is formally distinct from RTR harmony is an open question. For discussion, see Li (1996: 53), Svantesson *et al.* (2005: 8); note also Casali (2003).
- 9 In inflectional suffixes, /u/ is the only contrastive high vowel and the only trigger for height harmony. See Dyck (1995) and Campos-Astorkiza (2007) for discussion.
- 10 Paradis (1992) posits only five phonemic vowels.
- 11 Features may also belong to the root node itself, as has been suggested for major class features (Schein and Steriade 1986; McCarthy 1988).
- 12 A NoGAP constraint (or its equivalent) has been posited within Con, that is, the set of rankable constraints that compose an optimality-theoretic grammar. In some analyses it is undominated (Itô, Mester and Padgett 1995; Padgett 1995a), whereas in others it is violable within the patterns under study (e.g. Smolensky 1993; Uffman 2004).
- 13 Some of the other harmonies Shaw proposes, such as labial, are dissimilatory morpheme structure constraints or morphological affixation, rather than true consonant harmony.
- 14 This reasoning would not work for feature systems in which coronals and front vowels share specification (Clements and Hume 1995).
- 15 Hansson (2007b) has argued that the speech production explanation is not valid for all consonant harmonies, particularly those with secondary articulation. Those cases have unique diachronic explanations, often due to language contact and related to (re)interpretation of C-V coarticulation.
- 16 The model of aggressive reduplication (Zuraw 2002) employs a similar mechanism to couple substrings, but does not encode similarity directly.
- 17 In Rose and Walker (2004), directionality is added to the IDENT-CC constraint.
- 18 Hansson (2007a) argues that while lack of blocking is a descriptive characteristic of consonant harmony systems, it does not necessarily follow from the agreement-by-correspondence approach. See Hansson (2007a) for discussion of two scenarios under which blocking might arise.

- 19 Krämer (2001, 2003) develops a surface correspondence approach for vowel harmony, but builds adjacency at a moraic or syllabic level into the definition. Pulleyblank (2002) offers a different perspective that accounts for both vowel and consonant harmony using a “no-disagreement” harmony-driver (see also Archangeli and Pulleyblank 2007).
- 20 Cole and Kisseberth (1995a, b) propose an alignment-driven analysis of vowel harmony and nasal vowel-consonant harmony that posits *feature domains* in place of traditional autosegmental representations.
- 21 Other proposals have been made to treat some or all patterns of vowel harmony as driven by identity constraints among vowels which stand in a correspondence relation in the output (Kitto and de Lacy 1999; Krämer 2003).
- 22 Retroflex harmony in Kinyarwanda could prove a challenge for such analyses. Walker *et al.* (2008) find articulatory evidence that is consistent with an interpretation of the pattern as a regressive vowel-consonant harmony. However, the harmony appears to occur only when it extends to particular target consonants. Non-coronal consonants that precede a retroflex fricative trigger only show evidence of undergoing harmony in the presence of a preceding target, a fricative or flap.
- 23 Boersma (1998) also notes that reduction of articulatory contours could produce vowel harmony patterns.
- 24 See Baković (2000) for discussion of further issues presented by feature-driven markedness.
- 25 See Gick *et al.* (2006) for related acoustic research on the harmony system of Kinande (Bantu).
- 26 For other proposals with some related concepts, see Schane (1990) and Casali (1996 [1998]).
- 27 See Clements and Osu (2003) for an alternate perspective on defining the hierarchy.
- 28 Related issues for the treatment of glides arise surrounding their capacity to block nasal vowel-consonant harmony in some languages but not others. For discussion, see Cohn (1990, 1993b), Walker (1998 [2000]), Flemming (2004), Levi (2004, 2008), and Padgett (2008).
- 29 Lango vowel harmony is subject to a number of other complex conditions, including the condition that two intervening consonants do not block progressive harmony if the trigger vowel is high.
- 30 See Mester (1988) for a solution to identity effects in terms of dependent tier ordering.
- 31 An acoustic study by Gordon (1999a) of backness harmony in Finnish leads him to conclude that harmony functions at a low phonetic level for “transparent” /i/ and /e/. Svantesson *et al.* (2005) characterize /i/ as phonologically transparent to pharyngeal harmony in Halh, but their acoustic examination of this vowel reveals that it is realized as pharyngealized in pharyngeal words.
- 32 Such a system does occur with vowel-consonant emphasis harmony, but apparently not with vowel harmony.
- 33 Compound words may be considered a morphological word, but typically consist of two distinct harmonic domains, as in Finnish, Hungarian, or Turkana. Hoberman (1988) reports that in Azerbaijani Jewish Aramaic, emphasis harmony may sometimes extend to the other half of a compound. Suffixes added to compounds harmonize with the second half, forming a phonological word domain with the second portion which does not coincide with the morphological relationship of the suffix attaching to the whole compound.
- 34 The vowels were measured in monosyllabic stems without a suffix, which prevents vowel-to-vowel coarticulation from affecting the result.