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21. Vowel Height

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Sections

1 Introduction

While all languages have vowels, and all vowels can be described as having a height,[1] actually defining vowel height turns out to be a rather interesting problem (see also CHAPTER 19: VOWEL PLACE). Consider the systems in (1).

(1) *Sample vowel inventories*

a. *2 vowels*	b. *5 vowels*	c. *7 vowels*	d. *10 vowels*
i	i u	i u	i u
a	e o	e o	ɪ ʊ
	a	ɛ ɔ	e o
		a	ɛ ɔ
			ɐ
			a

It would be fairly uncontroversial to assume that a two-vowel system such as (1a) distinguishes between two vowel heights and that a five-vowel system such as (1b) distinguishes between three heights (although see below). The number of "heights" in the seven- and ten-vowel systems, however, depends on various factors. One view of a ten-vowel system such as (1d) is that it involves three "heights" (high, mid, low) cross-cut by a tongue-root feature; an alternative is that such a system involves a highly differentiated height feature with six heights. A seven-vowel pattern such as (1c) presents more analytic indeterminacy. One possibility is to analyze such a pattern as a simplified version of the ten-vowel system: a three-height system with a tongue-root distinction in the mid vowels, or a four-height system with a differentiated height pattern as in (1d), but with four rather than six distinctions. An additional possibility is to consider the seven-vowel and ten-vowel systems to be qualitatively different: while a ten-vowel inventory like (1d) could be analyzed as involving three heights plus a tongue-root distinction, a seven-vowel inventory like (1c) could be seen as involving four heights (and no tongue-root distinction).

The following sections discuss sample phonological patterns involving vowel height, considering the types of factors that bear on the analysis of such systems, both phonetic and phonological, as well as the types of proposals that have been made in the phonological literature for the formal instantiation of vowel height. It will be shown that "height" for some researchers reflects the operation of a single parameter, while for others it is the manifestation of several largely unrelated variables.

2 Phonetics of vowel height

There are three basic ways of defining vowel height phonetically: articulatorily, acoustically, and auditorily (**Ladefoged and Maddieson 1996**). These three possibilities produce rather different pictures of what vowel height might mean, none of which correspond unproblematically to the categories that seem relevant for phonology. Articulatorily, "vowel height" might be taken to suggest a dimension based on the height of the tongue body. While this is a convenient simplification for pedagogical reasons (see **Rogers 1991**: 170, who defines [height] as "a multivalued feature distinguishing vowels by the position of the highest point of the tongue"), it turns out that tongue body height is only sometimes correlated directly with phonological vowel height (**Ladefoged and Maddieson 1996**). Different ways of approaching vowel height articulatorily are possible, but none reproduces straightforwardly the sort of vowel space usually assumed by phonologists.

A plausible explanation for this discrepancy could be that vowel height depends more on the acoustic properties of the vocal tract than on any specific articulatory means of achieving the appropriate effect (**Elorrieta Puente 1996**). According to this view, vowel height could be acoustically defined in terms of the first formant, i.e. F1. This position was taken by **Ladefoged (1975**: 265), who defined the "prime feature [height] as the inverse of the frequency of the first formant." Although in later editions of Ladefoged's book the section on prime features was removed, the definition of height as correlating inversely with the value of the first formant was maintained (**Ladefoged 2006**: 188). While certainly an accurate indication of height in many instances, such an acoustic definition of height also appears to be inadequate in a number of cases. One example involves the determination of vowel height in languages with tongue-root advancement/retraction. As shown by **Lindau (1979)**, **Ladefoged and Maddieson (1996)**, **Gick *et al.* (2006)**, and others, some tongue-root harmony languages exhibit advanced mid vowels such as [e] that are "higher" (that is, lower F1) than the corresponding retracted high vowel such as [ɪ]. Such systems cannot assign vowels to a particular height solely on the basis of the value for the first formant.

Auditory characterizations of vowel height are adopted in much phonological work (**Lindau 1978**; **Casali 1996**). From introductory textbooks, to IPA charts, to research articles, we are accustomed to two-dimensional representations of vowels where "height" is represented on the vertical axis and backness is represented on the horizontal axis. In **Jones's (1972)** proposal for cardinal vowels, reference vowels were established on the basis of articulatory extremes ([i *a*]), with additional reference points defined in terms of auditorily equidistant steps.[2]

As we will see below, whether we consider height to be a notion that is primarily articulatory, acoustic, or auditory, or whether we consider it to crucially involve some combination of such factors, the phonology of height must resolve numerous questions whose answers do not clearly emerge from a consideration of properties of production or perception alone.

3 Vowel height typology

Before turning to the types of patterns that involve height, some cross-linguistic generalizations can be made about vowel inventories. Making typological generalizations about vowel height depends to a certain extent on whether features like [tense] and [ATR] ([Advanced Tongue Root]) are "height" features or not. For example, a ten-vowel system such as that of Degema (§4.3.2) has three vowel heights under the view that [ATR] is not a height feature and six vowel heights under the view that even ATR-like distinctions are height distinctions (whether formally using [ATR] or some other feature).

(2) *Degema: ten vowels*

[ATR] ∈ height			[ATR] ∉ height
Height 1	i	u	HIGH
Height 2	ɪ	ʊ	
Height 3	e	o	MID
Height 4	ɛ	ɔ	
Height 5		ə	LOW
Height 6		a	

Ultimately, however, the big picture seems remarkably similar no matter which assumption one makes. The following brief discussion of typological observations concerning height is based largely on the UPSID report in **Maddieson (1984)**; see also **Crothers (1978)**.

An initial remark concerns the use of Maddieson work in drawing conclusions on vowel height. Numerous issues arise; for example, how to count cases where there are different heights in oral and nasalized vowels, where the label for a back vowel is different from a potentially corresponding front vowel, and so on. In addition, Maddieson primarily distinguishes between a maximum of five vowel heights (high, higher mid, mid, lower mid, low), although he also makes a subdistinction between

"high" and "lowered high," "low" and "raised low." In the following remarks, both determinations of height are considered. Note that Maddieson does not employ a categorization of vowels based on [ATR], so the results are neutral as to whether a distinction between, say, "high" and "lowered high" or "higher mid" and "lower mid" should be a true height distinction or a height distinction cross-cut by an orthogonal tongue-root feature. In general, the numbers presented here are conservative in the sense that in cases of doubt I have underdifferentiated. For example, if there was a back vowel that was "higher mid" (with no corresponding front vowel) and if there was a front vowel that was "mid" (with no corresponding back vowel), then this would be counted as one height, not two; Songhai is such an example.

The results in terms of numbers of vowels of different heights are summarized in **Table 21.1**. Several points are noteworthy. There are no languages with a single height. While it is possible to have a vowel system that does not contrast vowels on the basis of backness/rounding, such is not found for vowel height. Whether or not one makes subdistinctions in the high or low vowels, the overwhelmingly most common height system is a three-height system. Four-height systems are well attested, while five-height systems are much less common and six-height systems are extremely rare. There seems little question that while a system like Degema raises interesting questions about the analysis of vowel height, it is a highly marked vowel inventory no matter what our assumptions about [ATR].

Number of vowel heights	*No subdistinctions (maximum = 5)*	*Subdistinctions included (maximum = 7)*
2	25 (8%)	25 (8%)
3	206 (65%)	200 (63%)
4	82 (26%)	76 (24%)
5	4 (1%)	15 (5%)
6	n/a	1 (0%)
Total	317 (100%)	317 (100%)

Table 21.1 Systems of vowel height

4 Phonological height patterns

In this section and the next, I focus on two aspects of vowel height: a sample of the kinds of phonological patterns that refer to vowel height (§4); the types of phonological representations that have been proposed for vowel height, the sorts of features that have been proposed and how they are organized (§5).

Whatever their intrinsic height values, vowels can be both raised and lowered. This section considers raising.

4.1.1 Raising to mid

Basque (language isolate; Spain and France; **Hualde 1991**) provides an example of vowel raising. Exemplified here from the Baztan dialect, low vowels raise to mid when following high vowels.

(3) *Basque raising*

	'wish'		'head'	
absolutive singular	/gogo-a/	gogoa	/buru-a/	burue
absolutive plural	/gogo-ak/	gogoak	/buru-ak/	buruek

The conditions for raising differ from language to language. For example, Gunu (Bantu, Niger-Congo; Cameroon; **Hyman 2001**) raises low vowels to mid, as does Basque, but exhibits raising after both high and mid vowels.[3] Compare (4a), illustrating the suffix [a], with (4b), illustrating the mid [e] that occurs after high and mid advanced vowels.

(4) *Gunu raising*

a.	fɛm-a	'hate'	b.	bid-e	'interrogate'
	fon-a	'bless'		fug-e	'mix'
	lab-a	'profit from'		déb-e	'flow'

Basque involves assimilation of a low vowel to the non-low feature of a high vowel, while Gunu involves assimilation of a low vowel to the non-low feature of both high vowels and mid advanced vowels. Such cases illustrate the need for the theory to establish high vowels as a class (*vs.* mid and low) in some languages, and high and mid vowels as a class (*vs.* low) in others.

4.1.2 Raising to high

Kera (Chadic, Afroasiatic; Chad) exhibits vowel raising (**Pearce 2003**). As seen in verbs and nouns with person suffixes, high vowels are dominant, in that a high vowel anywhere in a phonological word causes a non-high vowel to raise.[4]

(5) *Kera raising*

		root	-a (3FEM SG) 'her X; X her'	-i (2FEM SG) 'your (FEM) X; X you'	-u (3MASC SG) 'his X; X him'	
a.	/i/	/gi:d-/	gi:dɨ	gi:di	gi:du	'stomach'
	/ɨ/	/ʧɨ:(r)-/	ʧɨ:rɨ	ʧi:ri	ʧu:ru	'head'
	/u/	/gun-/	gunɨ	guni	gunu	'wake'
b.	/ɛ/	/sɛ:n-/	sɛ:na	si:ni	si:nu	'brother'
	/a/	/ka:s-/	ka:sa	kɨ:si	kɨ:su	'hand'
	/ɔ/	/gɔld-/	gɔlda	gulduj	guldu	'search'

Raising can apply to an affix; for example, the suffix /-a/ (3FEM SG) surfaces as low when the root vowel is non-high (5b) but raises to high when the root vowel is high (5a). Root vowels too may change; for example, the roots in (5a) are underlyingly high and surface as such when occurring with a suffix that also has a high vowel; but when a high suffix appears with a non-high root, as in (5b), the root vowel raises to high.

4.1.3 Chain shifts: One-step raising

Certain languages exhibit a pattern whereby vowels of different height raise by "one step"; for example, a low vowel becomes mid and a mid vowel becomes high (see CHAPTER 73: CHAIN SHIFTS). A well-known example is the Lena dialect of Spanish (Romance, Indo-European; Spain; **Hualde 1989**; **Parkinson 1996**). In this dialect, as in a number of related dialects, low vowels raise to mid when preceding the high vowel [u], while mid vowels raise to high in the same context.

(6) *Lena raising*

	fem sg	*masc sg*	
a → e	'gata	'getu	'cat'
e → i	'nena	'ninu	'child'
o → u	'koʃa	'kuʃu	'cripple'

Note crucially that vowels only raise by a single step in such a system: a low vowel raises to [e], but such a derived mid vowel does not undergo further raising to [i].

Another example of such incremental raising can be seen in the Servigliano dialect of Italian (Romance, Indo-European; Italy; **Parkinson 1996**; **Nibert 1998**). Metaphony in Servigliano distinguishes four vowel sets: [i/u] trigger metaphony, [e/o] and [ɛ/ɔ] undergo metaphony, and [a] is immune to metaphony (see also CHAPTER 110: METAPHONY IN ROMANCE).

(7) *Servigliano raising*

ɛ → e	mo'dɛst-a	'modest (FEM SG)'	mo'dest-u	'modest (MASC SG)'
ɔ → o	'mɔr-e	'he dies'	'mor-i	'you die'
e → i	'mett-o	'I put'	'mitt-i	'you put'
o → u	'spos-a	'wife'	'spus-u	'husband'
a (→ a)	'patr-e	'father (MASC SG)'	'patr-i	'father (MASC PL)'

Although the classes involved in Servigliano are slightly different from those of Lena, raising is again by one step, with [ɛ/ɔ] raising to [e/o] and underlying [e/o] raising to [i/u]. As in Lena, vowels raise by a single step; underived e/o raise to high

vowels but derived e/o are not similarly affected.

An example of this kind of chain shift involving changes to three distinct heights can be found in Njebi (Bantu, Niger–Congo; Gabon; **Guthrie 1968**; **Clements 1991**; **Parkinson 1996**). In Njebi, the verbal suffix [i], itself pronounced only in very careful speech, causes preceding vowels to raise. As seen below, [a] raises to [ɛ], [ɛ/ɔ] raise to [e/o], [e/o] raise to [i/u].

(8) *Njebi raising*

e → i	betə	biti	'carry'
o → u	βoomə	βuumi	'breathe'
ɛ → e	sɛbə	sebi	'laugh'
ɔ → o	sɔbəs	sobis	'foretell'
a → ɛ	salə	sɛli	'work'

As in the Lena and Servigliano examples, raising is by one step only. The raising is neutralizing in that the outputs of raising are possible input vowels, but raising is not self-feeding. A much discussed issue in the phonological literature on vowel height is how best to characterize such cases of chain shift; see §5.5.2.

4.2 Vowel lowering

Just as there are patterns of vowel raising, so are there patterns of lowering. This section samples such cases.

4.2.1 Lowering to mid

A common Bantu rule lowers high vowels to mid when following a mid vowel. This is illustrated here from Shona (Bantu, Niger–Congo; Zimbabwe; **Beckman 1997**).

(9) *Shona lowering*

a. *Suffixal* [i] *after low and high vowels*

ʃamb-a	'wash'	ʃamb-is-a	'make wash'
ip-a	'be evil'	ip-ir-a	'be evil for'
bvum-a	'agree'	bvum-is-a	'make agree'

b. *Suffixal* [e] *after mid vowels*

per-a	'end'	per-er-a	'end in'
tond-a	'face'	tond-es-a	'make to face'

Although this pattern of Bantu lowering is commonly triggered by mid vowels only, as in the Shona case just exemplified, some languages exhibit comparable lowering after all non-high vowels (**Hyman 1999**; **Linebaugh 2007**). **Hyman (1999)** illustrates such a pattern in Pende (Bantu, Niger–Congo; Democratic Republic of the Congo): In Pende, the applicative suffix /-il/ surfaces as high ([-il]) when the preceding root vowel is high but as mid ([-el]) when the preceding root vowel is mid or low.

(10) *Pende lowering*

a. *Suffixal* [i] *after high vowels*

gu-díg-íl-a	'sell for'
gu-túng-íl-a	'build for'

b. *Suffixal* [e] *after mid and low vowels*

gu-bemb-el-a	'abandon for'
gu-lómb-él-a	'ask for'
gu-sas-el-a	'chop for'

In Pende, the applicative suffix /-il/ surfaces as high ([-il]) when the preceding root vowel is high but as mid ([-el]) when the preceding root vowel is mid or low.

As with cases of raising, such cases illustrate the need for identifying different classes of vowels based on height: mid *vs.* high and low in Shona, mid and low *vs.* high in Pende.

4.2.2 Lowering to low

An interesting case of vowel lowering is found in Lardil (Pama–Nyungan; Australia; **Hale 1973**; **Kenstowicz and Kisseberth 1979**).

(11) *Lardil final vowel lowering*

	uninflected	*non-future*	*future*	
a.	mela	mela-n	mela-ɽ	'sea'
	wanka	wanka-n	wanka-ɽ	'arm'
b.	ŋuka	ŋuku-n	ŋuku-ɽ	'water'
	kaɭa	kaɭu-n	kaɭu-ɽ	'child'

While the examples in (11a) have a consistent [a] as their second vowel, those in (11b) alternate, exhibiting [u] in non-word-final position and [a] in word-final position. To postulate an underlying /a/ for (11b) would be problematic, since the vowel behaves differently from the consistent [a] of (11a). To postulate an underlying /u/ for (11b) is unproblematic, making the correct prediction that there should be no cases of this type with a word-final [u]. Hence such data motivate a pattern of word-final lowering to [a].

This case of lowering is different from the cases seen so far, in that it is position-ally triggered, not assimilatory. In addition, additional forms raise an interesting issue.

(12) *Lardil front vowels*

	uninflected	*non-future*	*future*	
a.	tjempe	tjempe-n	tjempe-ɽ	'mother's father'
	wiɭe	wiɭe-n	wiɭe-ɽ	'interior'
b.	ŋiɳe	ŋiɳi-n	ŋiɳi-wuɽ	'skin'
	pape	papi-n	papi-ɽ	'father's mother'

Comparable to (11), some forms show an invariant [e], while others show variation between word-final [e] and word-medial [i]. As with (11), this can be analyzed as involving /e/ for (12a) and /i/ for (12b), in conjunction with a rule of lowering.

It appears from such data that the result of lowering is low when /u/ is the target but mid when /i/ is the target. While possible, it should be noted that the vowel inventory of Lardil is {i e a u}. It appears, therefore, that Lardil distinguishes between only two heights, with both [e] and [a] constituting "low" vowels.

4.2.3 Chain shifts: One-step lowering

Paralleling the cases of stepwise raising seen above, cases of stepwise lowering are also attested. Esimbi (Bantu, Niger-Congo; Cameroon) is an intriguing case (**Hyman 1988**). There are three underlying prefix vowels and eight underlying stem vowels, but the underlying pattern is obscured since the height of the stem vowel is transferred to the prefix, the stem itself surfacing uniformly high. This height transfer is illustrated with the prefix vowel /I/ "class 9 singular," "class 10 plural."

(13) *Esimbi class 9/10 nouns*

	singular	*plural*	
/i/	ì-bì	í-bi	'goat'
/u/	ì-sùmu	i-sumu	'thorn'
/e/	è-gbì	é-gbi	'bushfowl'
/o/	è-nùnù	e-núnu	'bird'
/ə/	è-bi	e-bi	'canerat'
/ɛ/	ɛ̀-ɲìmì	ɛ-ɲimì	'animal'
/ɔ/	ɛ̀-fumù	ɛ-fumù	'hippo'
/a/	ɛ̀-kàrì	ɛ-kirì	'headpad'

With the highest stem vowels /i u/, the prefix surfaces as [i]; with the next highest stem vowels /e o ə/, the prefix surfaces as [e]; with the lowest stem vowels/ɛ ɔ a/, the prefix surfaces as [ɛ]. In each case the prefix vowel surfaces as a "palatal" vowel at the height corresponding to the stem vowel.

The two other prefix vowels are illustrated in (14) with /U/ "class 3 singular" and /A/ "class 6 plural."[5]

(14) *Esimbi class 3/6 nouns*

	singular	*plural*	
/i/	u-ɲimì	o-ɲimì	'grave'
/u/	ú-ku	ó-ku	'death'
/e/	o-jimbi	ɛ-jimbi	'song'
/o/	o-gúru	ɔ-gúru	'foot'
/ə/	ó-tɨ	ɔ-tɨ	'spear'
/ɛ/	ɔ-simi	a-simi	'grain'
/ɔ/	ɔ-gùnu	a-gùnu	'disease'
/a/	ɔ-kiri	a-kiri	'rope'

The singular prefix /U/ behaves in a fashion entirely analogous to /I/: in each case, the prefix is the "labial" vowel corresponding to the stem vowel's height. Hence the prefix is [u] with the highest stem vowels /i u/, [o] with the next highest stem vowels /e o ə/, and [ɔ] with the lowest stem vowels /ɛ ɔ a/.

Of interest is the behavior of the third possible prefix vowel, the vowel that is underlyingly low, illustrated by the plurals in (14). Instead of having the prefix height corresponding exactly to the underlying stem height, the low vowel has the effect of lowering the otherwise expected height by one step. This is summarized in (15).

(15) *Esimbi prefix height*

	prefix = /I/	prefix = /U/	prefix = /A/	stem height
highest stem	i	u	o	i u
next highest stem	e	o	ɛ/ɔ	e o ə
lowest stem	ɛ	ɔ	a	ɛ ɔ a
height generalization	prefix = stem	prefix = stem	prefix is one step lower than stem	

Like the cases of stepwise raising seen in §4.1.3, this kind of case involves a chain shift, but of stepwise lowering; see also §4.7.

4.3 Harmonic shifts

In addition to cases of raising and lowering, some patterns exhibit shifts towards the trigger, whatever its height. Two such patterns are considered in this section.

4.3.1 Shift to height of trigger

In a number of the cases discussed so far, notably the chain shift cases, a target vowel assimilates to a trigger vowel without becoming identical to it with respect to height. There are cases, however, where height assimilation involves a target becoming identical to a trigger with respect to its height specifications.

Consider lowering in Matumbi (Bantu, Niger-Congo; Tanzania; **Odden 1991**). When the causative suffix, which Odden analyzes as being underlyingly high and advanced (16a), (16b), (16g), follows a high retracted vowel, it is realized as high retracted (16c), (16d); when it follows a mid vowel, it is realized as mid (16e), (16f).

(16) *Matumbi*

a.	út-a	'pull'	út-ij-a	'make pull'
b.	jíb-a	'steal'	jíb-ij-a	'make steal'
c.	jójʊʊt-a	'whisper'	jójʊʊt-ɪj-a	'make whisper'
d.	bíɪk-a	'put'	bíɪk-ɪj-a	'make put'
e.	gɔ́ɔndʒ-a	'sleep'	gɔ́ɔndʒ-ɛj-a	'make sleep'
f.	ʧéɛŋg-a	'build'	ʧéɛŋg-ɛj-a	'make build'
g.	káat-a	'cut'	káat-ij-a	'make cut'

In a pattern of this type, the height assimilation involves trigger-target identity for height. Moreover, it should be noted that more than two "heights" are involved in this shift; identity is not a result simply because the system distinguishes only between high and non-high vowels.

4.3.2 Harmony

Whether harmonic patterns based on vowel height are considered common or rare depends in part on whether "ATR"-like systems are considered to be height harmony. If [ATR] is a height feature, then height harmonies are quite common; if [ATR] is a place feature, then "height"-based harmony systems appear less common (CHAPTER 19: VOWEL PLACE). Nevertheless, even abstracting away from cross-height harmony systems of the "ATR" type, harmonic systems based on height do occur; for discussion of a wide variety of systems, see **Linebaugh (2007)**.

In this section, a small number of harmonic systems based on height are considered, including systems of the cross-height "ATR" type. It should be noted, however, that "harmony" is used as a descriptive term only: there is no incontrovertible reason to think that there is a formally definable type of phonological pattern corresponding to those patterns we consider to be harmonic (**Archangeli and Pulleyblank 2007**).

To start, C'Lela (Benue-Congo, Niger-Congo; Nigeria) presents a particularly interesting case of height harmony (**Dettweiler 2000**; **Pulleyblank 2002**). In C'Lela, within a morpheme, only vowels of like height may co-occur: high vowels may co-occur, non-high vowels may co-occur, but vowels of mixed height may not.[6]

(17) *C'Lela root-internal harmony*

	High vowels			*Non-high vowels*	
a.	dᵊtɨndi	'nest'	b.	kwesa	'show'
	ʧᵊrinɨ	'charcoal'		ʧᵊgjɔmbo	'eyebrows'
	kᵊpɨru	'flower'		dᵊvɛso	'broom'

Harmony also manifests itself beyond the root. As illustrated in (18), direct objects exhibit variable behavior. Certain pronouns are harmonic, surfacing as a high vowel after a high root and as a non-high vowel after a non-high root.

(18) *C'Lela: The harmonic class*

	High root		*Non-high root*	
mi/me (1SG)	buzᵊkᵊ mi	'chased me'	ɛpkᵊ me	'bit me'
	sipkᵊ mi	'grabbed me'	wegaka me	'indicated me'
vu/vo (2SG)	buzᵊkᵊ vu	'chased you'	ɛpkᵊ vo	'bit you'
	sipkᵊ vu	'grabbed you'	wegaka vo	'indicated you'

Such harmonic behavior is not found for all pronouns, however. As seen in (19), 3rd person and plural pronoun objects do not harmonize.

(19) *C'Lela: The disharmonic class*

	High root		*Non-high root*	
o (3SG)	sipkᵊ o	'grabbed him'	wegaka o	'indicated him'
na (1PL INCL)	sipkᵊ na	'grabbed us'	wegaka na	'indicated us'
ʧo (1PL EXCL)	buzᵊkᵊ ʧo	'chased us'	batkᵊ ʧo	'released us'
no (2PL)	buzᵊkᵊ no	'chased you'	batkᵊ no	'released you'
nɨ (3PL)	fumtᵊkᵊ nɨ	'pulled them'	batkᵊ nɨ	'released them'
e (3PL INANIM)	hinᵊkᵊ e	'uprooted them'	kedᵊkᵊ e	'picked them'

In all but the case of [nɨ], these non-alternating morphemes are non-high. **Pulleyblank (2002)** therefore suggests that outside of the root, C'Lela behaves analogously to the lowering cases seen in §4.2.1: high vowels lower to mid after a non-high vowel; non-high vowels are unaffected.

Another example of harmony has already been seen in §4.1.2, the case of Kera raising. Two differences can be noted between the C'Lela and Kera patterns of harmony. First, as discussed by **Pearce (2003)**, within the root domain, Kera exhibits complete agreement between vowels, where C'Lela exhibits only agreement in height. Second, where C'Lela lowers high vowels across morpheme boundaries, Kera raises non-high vowels.

A very large class of harmony patterns involving height is the class of tongue-root harmony systems. Although there is a lot of variation in the behavior of such harmonic systems (**Archangeli and Pulleyblank 1994**), a fairly canonical pattern is one where vowels fall into two classes, advanced vowels and retracted vowels, where roots may only exhibit vowels from a single class, and where affixes attached to such roots surface with the same tongue-root value as observed in the root. Such cases have been referred to as "cross-height" harmony systems, since vowels of the advanced class co-occur whether they are "high," "mid," or "low," as do vowels of the retracted class.

Consider Degema (Edoid, Niger-Congo; Nigeria; **Kari 1997, 2003**). There are five advanced vowels {i e ə o u} and five

retracted vowels {ɪ ɛ a ɔ ʊ}, with stems selecting all their vowels from a single class.

(20) *Degema stems*

a. *Advanced*		b. *Retracted*	
gbodí	'catch'	fʊwɔ́	'be cool (of food)'
gurón	'postpone'	ganɛ́	'have as one's lover'
ɗímé	'submerge'	hɔβá	'bail out water from a canoe, etc.'
lebə́	'be partially ripe (of fruits)'	sɪgɔ́m	'jump with one leg folded'

Prefixes in Degema must agree in their tongue-root value with vowels of the stem. Consider, for example, noun class prefixes such as those in (21), where (21a) exhibit advanced values and (21b) retracted values.

(21) *Degema prefixes*

a. *singular*	*plural*		b. *singular*	*plural*	
u-túm	ə-túm	'tail'	ʊ-ɗɔ́m	a-ɗɔ́m	'marriage'
o-kpokí	i-kpokí	'money'	ɔ́-hɔ́hɔ	í-hɔ́hɔ	'fowl'
e-kúnési	i-kúnési	'bed'	ɛ-ɗɔ́ŋʷ	ɪ-ɗɔ́ŋʷ	'throat'
ə́-milíβə	í-milíβə	'night heron'	a-ɗú	ɪ-ɗú	'face'

Although less common than prefixes in Degema, suffixes also agree in their tongue-root value with the stem to which they attach. Consider examples of the gerundive.

(22) *Degema suffixes*

a. *Advanced*		b. *Retracted*	
ù-dér-ˈə́m	'cooking'	ò-tɛ́v-ˈám	'descending'
ù-vój-ˈə́m	'fetching'	ò-sɔ́l-ˈám	'jumping'

Overall, height harmony systems are amply attested and instantiate the typical range of variables discussed in the harmony literature: dominant/recessive *vs.* root-controlled patterns, transparency *vs.* opacity, directionality, and so on. There are also cases illustrating interesting interactions with stress; see, for example, **Fitzgerald (2002)**; **Walker (2005)**.

4.4 Neutralization

A large and interesting class of patterns involving vowel height is that of large-scale neutralization in languages where different vowel inventories are attested in different positions (**Crosswhite 2001**). An example is Catalan (Romance, Indo-European; Spain; **Mascaró 1983**):

(23) *Catalan vowel reduction*

Stressed			*Unstressed*		
/i/	ˈprim	'thin'	[i]	əpriˈma	'to make thin'
/e/	ˈserp	'snake'	[ə]	sərˈpɔtə	'big snake'
/ɛ/	ˈpɛl	'hair'		pəˈlut	'hairy'
/a/	ˈsak	'sack'		səˈkɛt	'small sack'
/ɔ/	ˈpɔrt	'harbor'	[u]	purtuˈaɾi	'related to harbor (ADJ)'
/o/	ˈgos	'dog'		guˈsas	'big dog'
/u/	ˈáum	'light'		áumiˈnos	'light (ADJ)'

As illustrated in (23), seven vowels are found in stressed positions in Catalan, but these distinctions collapse to three when the corresponding vowels appear in unstressed positions. In stressed positions, three or four vowel heights are distinguished, depending on one's analysis of the vowels [e/o] *vs.* [ɛ ɔ]; in unstressed positions, a two-way vowel height distinction is observed. This case illustrates a general pattern where fewer vowel heights are exhibited in positions of reduction than in positions of full contrast (CHAPTER 79: REDUCTION). Note in this regard that the Catalan case exhibits no loss of "color" distinctions, that is, distinctions involving [back] and [round].

4.5 Interactions between consonants and vowel height

Although the focus of this chapter is vowels, not all issues of vowel height are restricted to vowels. There are numerous examples of consonant–vowel interactions where vowel height is relevant, involving vowels affecting consonants as well as consonants affecting vowels. Samples of both types are considered in this section. (See also CHAPTER 75: CONSONANT–VOWEL PLACE FEATURE INTERACTIONS for some related phenomena.)

4.5.1 Vowels affecting consonants

As a first example of vowels affecting consonants, consider assibilation in Canadian French (Romance, Indo-European; Canada; **Dumas 1978**; **Walker 1984**). The coronal stops [t d] surface without change when before non-high or back vowels (e.g. [taRt] 'pie', [tɛm] 'topic, theme', [do] 'back', [dã] 'tooth'), but they become affricates before high front vowels or glides.

(24) *Canadian French assibilation*

[ts]			[dz]	
[i]	pətsi	'small'	ʒødzi	'Thursday'
[ɪ]	tsɪg	'tiger'	ʒʏʀɪdzɪk	'legal'
[ɪʲ]	etsɪʲʀ	'stretch'	dzɪʲʀ	'say'
[j]	tsjɛd	'lukewarm'	dzjɛt	'diet'
[y]	tsynɛl	'tunnel'	ʀãdzy	'returned'
[ʏ]	tsʏb	'tube'	pãdzʏl	'pendulum'
[ʏʸ]	fʀɪtsʏʀ	'frying'	dzʏʸʀ	'hard'
[ɥ]	tsɥil	'tile'	ʀedzɥɪʲʀ	'reduce'

Assibilation takes place whether the trigger is rounded or unrounded, tense or lax, a monophthong or a diphthong, a vowel or a glide. **Dumas (1978)** takes this as evidence that the distinction between the tense vowels [i y] and their lax counterparts [ɪ ʏ] (which is determined allophonically by syllable structure) is not a difference of vowel height. Auditorily, he argues that there is no significant difference between the mid vowels [e ø o] and the high lax vowels. Consequently, if laxing involved a change in height, we would expect lax vowels not to be assibilation triggers; that they are triggers suggests that the laxing process affects a dimension other than height.

These examples constitute one small example from the large class of palatalization cases attested cross-linguistically (see CHAPTER 71: PALATALIZATION). They are of relevance to vowel height since height is a typical delimiter on the class of vowels that triggers such processes.

A rather different type of consonant–vowel interaction is found in Chumburung (Kwa, Niger-Congo; Ghana; **Snider 1984**): [l] (a lateral) and [r] (a "lightly-retroflexed alveolar flap") are in complementary distribution. For some speakers, the distribution is unrelated to vowels, with [l] occurring in word and noun-stem-initial position ([lɔ́sɛ́] 'difficult'; [ki-lìmpɔ́] 'shea nut') and in a syllable following another [l] ([lóolí] 'deep'), while [r] occurs elsewhere ([jono-ro] 'in (the) dog'). For some speakers, however, this allophonic pattern between [l] and [r] interacts with vowel harmony, a pattern in Chumburung that is largely analogous to the tongue-root harmony system seen for Degema in §4.3.2, with the difference that Chumburung has a single (retracted) low vowel. For the relevant speakers, medial [l] only surfaces after another [l] if the vowels are in the [+ATR] set:

(25) *Chumburung [l] ~ [r]*

a.	[+ATR]		b.	[−ATR]	
	làlàkwì?	'type of tuber'		làarí	'waist'
	lóolí	'deep'		lɔɔrí	'to remove seeds'
	àlúulá?	'red dye'		làarɔ́	'to lie across'

Alternations can be observed under suffixation.

(26) *Chumburung suffix alternations: /-rɔ/* (LOCATIVE)

a.	jono-ro	'in (the) dog'
b.	kanɔ-rɔ	'in (the) mouth'
c.	lɔ-rɔ	'in (the) sore'
d.	laale-lo	'in (the) cattle egret'

Since the suffix-initial consonant is neither word-initial nor stem-initial, it would be correctly expected to surface as [r] in the

default case (26a, 26b) and even after [l] if the vowel harmony class is [–ATR] (26c); if the suffix follows an [l], however, and if the harmonic class is [+ATR], then the suffix surfaces with [l] (26d).

This particular kind of case is irrelevant if [ATR] is not a height feature. The point, however, is that height and/or tongue-root distinctions in vowels condition a range of consonantal effects: palatalization, differences in liquids, differences between velars and uvulars (**Li 1996**), and so on.

4.5.2 Consonants affecting vowels

Elorrieta Puente (1996) considers a wide range of cases where consonants affect vowel height, identifying two principal types of cases: (a) raising, triggered typically by palatals, palato-alveolars, or glides; (b) lowering, triggered typically by uvulars, pharyngeals, laryngeals, or rhotics. (See also **Vaux (1996, 1998)** and **Fitzgerald (2002)** for cases involving laryngeal features; and **CHAPTER 25**: PHARYNGEALS.)

Consider first an example of raising, taken from Kikuria (**Wiswall 1991**; **Elorrieta Puente 1996**). The relevant example involves a pattern of vowel raising triggered by both vowels any consonants. When a mid vowel prefix appears before a non-high stem vowel, the prefix surfaces as mid.[7]

(27) *Kikuria mid vowel prefixes*

oko-raara	'sleep'
oko-roma	'bite'
oko-gɛra	'weed'

In contrast, when such a prefix occurs before a high vowel stem, the prefix raises to high.

(28) *Kikuria raising: High vowel triggers*

uku-rugja	'chase'
ugu-siika	'close a door'

Of particular interest, the mid vowel of the prefix is also raised if the first syllable either contains a glide [j w] or a palatal consonant [tʃ ɲ].

(29) *Kikuria raising: Consonantal triggers*

ugu-tweeba	'forget us'
uku-bjoora	'remove from water'
ugu-ʧɔɔra	'draw'
ukuu-ɲandekera	'write for me'

In such cases, it is perhaps unsurprising that glides behave in a manner comparable to vowels, since glides are simply the non-syllabic counterpart of the high vowels that are canonical triggers of raising (**CHAPTER 15**: GLIDES). For the non-glides, the fact that palatals and alveo-palatals are triggers of raising in Kikuria but that velars are not is typical of such raising patterns cross-linguistically. Being "high" seems to be required of a consonantal trigger, but assuming that velars are also high means that simply being high is not sufficient in Kikuria.

With respect to lowering, the typical case is one where lowering is induced by the class of gutturals. Although this class may vary somewhat from language to language, it is generally defined by segments articulated in the post-velar region. Consider, for example, lowering in Gitksan (Tsimshianic; Canada; **Brown 2008**), illustrated here with plural reduplication. As seen in (30), there is a class of plurals formed by the prefixation of either C*i*(C)- or C*ix*-.

(30) *Gitksan plural reduplication*

saksxʷ	six-saksxʷ	'be clean'
dzam	dzim-dzam	'cook, boil (TRANS)'
ɬak	ɬi-ɬak	'be crooked'
gʷalkʷ	gʷil-gʷalkʷ	'be dry'

When the vowel of the reduplicative prefix precedes or follows a uvular or a laryngeal, the vowel lowers to [a].

(31) *Gitksan lowering*

dzoq	dzaχ-dzoq	'camp'
getxʷ	ga-getxʷ	'be difficult, be expensive'
go:t	ga-go:t	'heart'
hets	has-hets	'send'
ʔos	ʔas-ʔos	'dog'

The Gitksan pattern is one where lowering is triggered by uvulars and laryngeals. Perhaps more typical would be a case where vowels are lowered by a "guttural" class including pharyngeals (CHAPTER 25: PHARYNGEALS). Setting aside the presence/absence of pharyngeals, languages exhibiting lowering differ as to whether laryngeals are included (e.g. Arabic, Semitic, Afroasiatic; **McCarthy 1994**) or excluded (e.g. Nuu-chah-nulth, Wakashan; Canada; **Wilson 2007**); see **Rose (1996)**.

Two final patterns touched upon here are ones where two input vowels merge into a single output vowel (coalescence) and where a single vowel splits into more than one component (diphthongization).

4.6 Coalescence

Patterns of vowel coalescence are frequently height-dependent. Consider the following examples from Anufɔ (Kwa, Niger-Congo; Ghana; **Casali 1996**).

(32) *Anufɔ vowel contact*

a.	/jɛ-i/	jɛ:	'raise it'
b.	/ʤɔ-u/	ʤɔ:	'cool you'
c.	/bu-i/	bwi:	'break it'
d.	/fa-i/	fɛ:	'take it'
e.	/bo-i/	bwe:	'beat it'
f.	/sɔ-i/	swɛ:	'carry it'
g.	/fa-u/	fɔ:	'take you'
h.	/bo-u/	bo:	'beat you'
i.	/n-de-u/	ndo:	'I will take it for you'

Different subcases are of interest for different, though related, reasons. In examples like (32a), (32b), the output contains no discernible trace (other than length) of the high vowel in the input. In cases like (32c), (32e), (32f), labiality is never lost, resulting in a glide-vowel sequence when the first vowel of the sequence is labial and the second vowel is not. The cases of particular interest for vowel height, however, are ones like (32a), (32b), (32e), (32f), (32h), (32i), on the one hand, and (32d), (32g), on the other. In the former type, we see that the combination of a mid vowel with a high vowel results in a long mid vowel; in the latter type, we see that the combination of a low vowel and a high vowel also results in a long mid vowel. Note in particular that the output of a low-high sequence is neither low nor high, but an intermediate vowel.

The pattern observed in Anufɔ is typical in terms of what **Casali (1996)** refers to as "height coalescence." He observes that coalescence is frequent in cases where V1 is non-high (e.g. [a]) and V2 is higher than V1 (e.g. [i] or [u]), the result being non-high with the place properties of V2. The results in (32d), (32g) are canonical with respect to this pattern. For an in-depth discussion of such patterns, along with the identification of robust subpatterns, see **Casali (1996)**.

4.7 Diphthongization

In patterns of diphthongization, vowel height is frequently an important variable, with diphthongs related to a set of corresponding monophthongs in ways defined at least in part by vowel height. This can be illustrated with data from Canadian French (Romance, Indo-European; Canada; **Dumas 1981, 1987**; **Hayes 1990**).

As seen in (33), long vowels in non-final unstressed position correspond to diphthongs in final stressed position. The diphthongs, like the corresponding monophthongs, are heavy.

(33) *Alternations involving diphthongs in Canadian French*

baⁱt	'stupid'	bɛːtsɪⁱz	'stupidity'
ãpaⁱʃ	'prevent'	ãpɛːʃe	'to prevent'
naⁱʒ	'snow'	nɛːʒa	'snowed'
pɑᵘl	'pale'	pɒːlɪⁱʀ	'fade'
ʀɑᵘʀ	'rare'	ʀɒːʀmã	'rarely'
ekʀɑᵘz	'crush'	ekʀɒːze	'to crush'

Dumas (1981) notes that the first half of the diphthong is one notch lower in terms of height than the corresponding monophthong, while the second half tends to raise towards the position of a high vowel. These correspondences are schematized and exemplified in (34) (examples taken from **Dumas 1987**).

(34) *Correspondences between monophthongs and diphthongs in Canadian French*

[iː]	↔	[ɪⁱ]	fʀɪⁱz	'curl'
[eː]	↔	[ɛⁱ]	pɛⁱʀ	'father'
[ɛː]	↔	[aⁱ]	tãpaⁱt	'storm'
[yː]	↔	[ʏʸ]	ʒʏʸʀ	'swear'
[øː]	↔	[œʸ]	nœʸt	'neutral'
[œː]	↔	[aʸ]	plaʸʀ	'cry'
[uː]	↔	[ʊᵘ]	ʀʊᵘʒ	'red'
[oː]	↔	[ɔᵘ]	kɔᵘt	'coast'
[ɔː]	↔	[ɑᵘ]	ãkɑᵘʀ	'again'
[ɒː]	↔	[ɑᵘ]	kɑᵘd	'frame'

These cases, like those in §4.2.3, involve a one-step chain shift based on vowel lowering.

5 Features for height

Approaches to defining a set of distinctive features for vowel height vary in two fundamental ways. First, a decision must be made about whether features like [ATR] should be posited, or not, and if so whether they should be considered to be "height" features. Second, height can be characterized in terms of a single gradient feature or in terms of a set of interacting features (CHAPTER 17: DISTINCTIVE FEATURES). In the discussion below, a sample of the approaches found in the literature for vowel height will be presented, presenting a range of views on such issues.

5.1 Features constituting "height"

As discussed in §2, there is no way a priori to decide that a particular feature should be a height feature. For example, [ATR] might be classified as a "height" feature if acoustics was taken as definitional (due to its effect on F1), but not as a "height" feature if articulatory tongue body height was taken as definitional. Consequently, theories vary as to whether [ATR] is included as a feature or not (**Clements and Hume 1995**; **Vaux 1996**), and if it is a feature, whether it is a height feature or not. For example, **Clements (1990)** and **Clements and Hume (1995)** discuss the possibility that [ATR] could be eliminated; **Odden (1991)** maintains a feature [ATR], arguing that it is under a "height" node that dominates [high], [ATR], and (perhaps) [low]; **Parkinson (1996)** proposes a "height" constituent consisting solely of instances of the feature [closed], with [ATR] analyzed outside of the "height" node as a place feature; **Elorrieta Puente (1996**: 6) considers that "height" involves a single feature composite of the dimensions "high–low, tense–lax, and advanced–nonadvanced tongue root." Similar issues arise about potential height features involving tenseness and peripherality.

An additional issue affecting featural analyses of height involves the division of vowels, particularly "lowish" vowels, into classes. **Parkinson (1996**: 117–119), for example, argues that although Njebi, Basaa and Efik all have the vowels {i e ɛ a ɔ o u}, the breakdown of the three inventories into vowel heights is different in each case.[8] For Njebi, as seen in (8) above, four heights need to be distinguished since vowel raising distinguishes between four classes: [a] raises to [ɛ]; [ɛ ɔ] raise to [e o]; [e o] raise to [i u].

(35) *Differing interpretations of comparable vowels*

a. *Njɛbi*

Height 1	[i u]
Height 2	[e o]
Height 3	[ɛ ɔ]
Height 4	[a]

b. *Basaa*

Height 1	[i u]
Height 2	[e o]
Height 3	[a ɛ ɔ]

c. *Efik*

Height 1	[i ɨ u]
Height 2	[e ɛ a ɔ o]

In contrast, raising in Basaa involves only three heights: [a ɛ ɔ] raise to [e o]; [e o] raise to [i u]. Finally Efik distinguishes two heights: [i ɨ u] *vs.* [e ɛ a ɔ o]. Those vowels not distinguished by height are differentiated by place specifications like [labial], [coronal], and [pharyngeal]. Overall, establishing appropriate specifications for vowel height is a complex problem involving the analysis of both height and place and, depending on the theory, analyses of superficially similar inventories may vary considerably from language to language.

A number of proposals for height are considered below, including what the features are and how they are situated within a broader theory of feature composition and structure.

5.2 Features: [high] and [low]

Following **Chomsky and Halle (1968**; *SPE*), the dominant approach to vowel height over the years has been to base vowel height on the interaction of two binary features, [±high] and [±low].

(36) *Feature definitions* (*SPE*: 394–395)

a. [±high]
High sounds are produced by raising the body of the tongue above the level that it occupies in the neutral position; non-high sounds are produced without such a raising of the tongue body.

b. [±low]
Low sounds are produced by lowering the body of the tongue below the level that it occupies in the neutral position; non-low sounds are produced without such a lowering of the body of the tongue.

Together, these features define three vowel heights, the possibility of [+high, +low] being ruled out by the definitions of the two features.

(37) *Defining vowel heights*

	High	Mid	Low
[high]	+	−	−
[low]	−	−	+

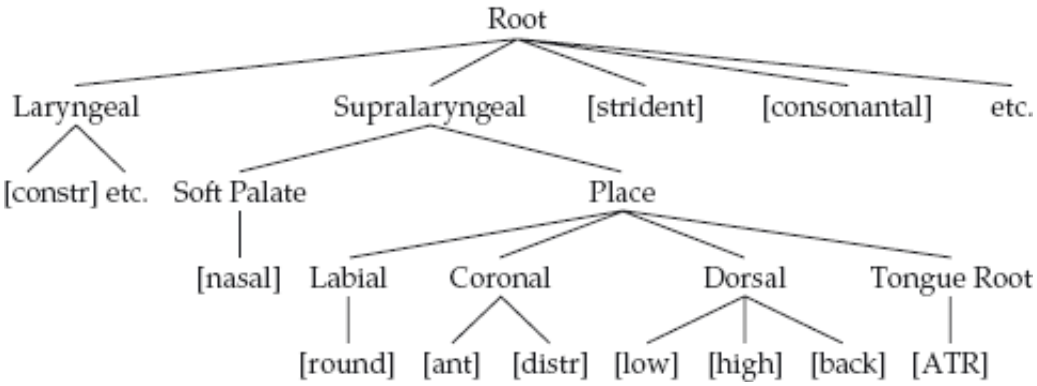
In defining a maximum of three vowel heights, this approach requires that additional, non-height features interact with [±high] and [±low] to define a full range of vowel contrasts. For example, [±tense] and [±covered] are proposed in *SPE*.

A particularly important point to note about this kind of theory (**Parkinson 1996**) is that vowel height plays no formal role: there is no class of "height" features in any formal sense. While it is possible within the *SPE* model for a rule to refer to the two features [±high] and [±low], such a pair has no formal status that is different from, say, [±high] and [±back], or [±high] and [±nasal]. Within that theory, distinctive features constitute an unstructured set, and any combination of features can constitute the set employed in a given rule.

5.3 Feature geometry with [high] and [low]

This lack of formal "height" features is a property that has continued to be adopted in numerous subsequent theories of vowel features. For example, in the influential work of **Sagey (1986, 1990)** on feature geometry, the features [±high] and [±low] continue to be assumed, assigned as two of the three features of the Dorsal articulator node.

(38) *The feature hierarchy in Sagey* (1990: 113)



As in the unstructured approach of *SPE*, this featural organization assigns no status to vowel height since no node dominates specifically [low] and [high]; if [ATR] is considered a "height" feature, there is no node specifically dominating [low], [high], and [ATR].

Interestingly, this type of hierarchical organization actually goes beyond the lack of status seen in *SPE*. In the *SPE* proposal, it is possible for a rule to target the two features [low] and [high], even granted that there is no special status for those two features in particular; a rule of the type X → [αhigh, βlow]…is perfectly well formed. In the **Sagey (1986, 1990)** model, as well as in work such as **Halle (1995)**, **Vaux (1996, 1998)**, and **Halle *et al.* (2000)**, in contrast, it is impossible to refer to [low] and [high] as a single class to the exclusion of other features. If a rule targets the Dorsal node, then backness as well as height is targeted; if a rule targets Place, Supralaryngeal, or Root, then a large number of non-height features are selected in addition to the height features. The prediction of the Sagey hierarchy is therefore that there should be no rules targeting height features to the exclusion of features such as place.

5.4 Arguments for a height class

Two types of arguments have been presented against the type of model presented in (38). On the one hand, there are arguments directly in favor of a height class, a class that excludes place of articulation features; on the other hand, there are also indirect arguments in favor of a height class, based on examples where the place of articulation of vowels assimilates without affecting vowel height (see also **CHAPTER 27**: THE ORGANIZATION OF FEATURES). I will give a sample of the types of arguments in favor of a height class in this section, referring the reader to work such as **Clements (1990)** and **Parkinson (1996)** for arguments in favor of place as a class.

Gbe languages (Kwa, Niger-Congo; Benin, Togo, Ghana) exhibit an intricate set of vowel assimilations involving height (**Clements 1974, 1990**; **Capo 1985**). On the basis of stepwise raising (§4.1.3), **Clements (1990)** argues that three vowel heights should be distinguished in Gbe.

(39) *Pandialectal vowel height in Gbe*

	oral			*nasal*		
height 3	i		u	ĩ		ũ
height 2	e	ə	o		ə̃	
height 1	ɛ	a	ɔ	ɛ̃	ã	ɔ̃

Specific Gbe languages/dialects exhibit subsets of these vowels.

Assimilatory behavior in the copular suffix provides evidence for height assimilation. As seen in the following examples from the Adangbe dialect of Ewe (Ghana), the suffix is [i] after a height 3 vowel, [e] after a height 2 vowel, and [ɛ] after a height 1 vowel.

(40) *Height assimilation in Ewe*

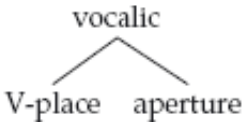
	stem vowel		
height 3	[i]	àsi-í	'it's water'
	[u]	àvù-í	'it's a dog'
height 2	[e]	əje-é	'it's a spider'
	[ə]	əɲe-é	'it's me'[9]
	[o]	əwo-é	'it's you'
height 1	[ɛ]	àʊlɛ-ɛ́	'it's a weaver bird'
	[a]	àgbɛ̀-ɛ̀'	'it's a load'[10]
	[ɔ]	àsɔ́-ɛ́	'it's a horse'

If such assimilation is to be given "unit" status, then features for vowel height must be distinguished from vowel place, with a rule spreading specifically vowel height.

5.5 Properties of a height class

The response to arguments such as those presented in §5.4 has been to establish a vowel height node, labeled "aperture" by **Clements (1990)**, which is independent of place (**Clements 1990**; **Odden 1991**; **Wiswall 1991**; **Goad 1993**; **Elorrieta Puente 1996**; **Parkinson 1996**; etc.). Typically, both place and height are considered to be daughters of a vocalic node. For example, **Clements and Hume (1995)** propose a vocalic node branching into place features ("V-place") and height features ("aperture").

(41) *Distinguishing place and height*



Of specific importance with respect to the characterization of vowel height, the featural content of the aperture/height node must be determined.

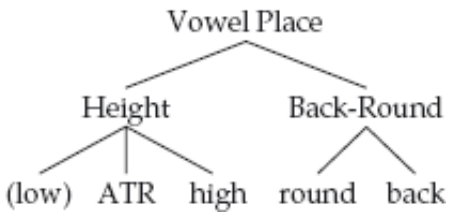
While the formal instantiations of this kind of proposal are relatively new, the conceptualization of speech sounds being composed of specifications for classes of features goes back to the International Phonetic Alphabet. As argued by **Ladefoged and Halle (1988)**, the IPA constitutes a theory of segment structure, and in the IPA theory, vowel height is explicitly recognized as an important class. In the following sections, a sample of the proposals for formally characterizing the vowel height class are laid out.

Ideally, a survey such as this one would carefully examine the arguments that have been presented for specific models, examining both successes and problems. Given the limited scope of this chapter, however, much of the discussion below will not go beyond a brief introduction. The reasons for this go beyond simple limitations on space. To adequately address the success of a given proposal, one needs to consider at least three things: (a) the validity of the empirical claims; (b) the predictions concerning natural classes, and how such predictions match the empirical generalizations; (c) how the theory of vowel height interacts with the overall theory of phonology. Examples of these considerations will be given below, but they will not be investigated in detail for each theory presented.

5.5.1 Grouping [high] and [ATR]

Odden (1991) argues for grouping [ATR] with [high] under a "height" node.[11]

(42) *Height node*



As seen in Matumbi (§4.3.1), both the features [high] and [ATR] together are affected by height assimilation but not the feature(s) for backness and rounding; see the data in (16). On the basis of such data, Odden proposes that it is the "height" node that assimilates. In making the argument, Odden explicitly addresses the alternative possibility that assimilation is the

combined result of assimilating [ATR] and [high] independently. He rejects such a "two-rule" analysis on two grounds. First, neither assimilation of [high] nor assimilation of [ATR] applies when the potential trigger is [ɛ] and the potential target is [u]; Odden suggests that this condition should be stated once, not twice. Second, morphemes that are exceptional to one type of assimilation are exceptional to both, again suggesting a unified analysis of the "two" processes.

The hierarchy in (42) is a natural development of the approach to vowel height in *SPE*, in that the features [low], [high], [back], and so on continue to be posited; see also **Wiswall (1991)** and **Goad (1993)**. The distinction is that these features are assigned class status, with a bifurcation between the features defining height and those defining place.

A fundamental observation that can be made about this type of proposal is that vowel height as a class is defined by the interaction of formally independent sub-height features. Features like [high], [low], and [ATR] may function as three individual, independent features, or they may function together as the height class. In contrast with such an approach, numerous researchers have proposed that height should be viewed in a more integrated fashion, as will be discussed below. In discussing the various possible approaches that have been taken to gradient height, it is important to keep one central point in mind. Independent of one's precise proposals for vowel height, it is possible to consider [ATR] as being a height feature (and therefore integrated into the gradient height framework) or as being a place feature (and therefore independent of gradient height). The issue of tongue-root involvement is therefore a matter to be resolved in one way or the other for all proposals.

5.5.2 Gradient height

Amongst the early proposals for a gradient height feature are **Ladefoged (1975)** and **Lindau (1978)**. A central argument in favor of gradience comes from chain shift cases such as those seen in §4.1.3, §4.2.3, and §4.7. **Lindau (1978)** discusses the case of diphthongization in Scanian, a dialect of Swedish (although see **Yip 1980** for arguments against Lindau's analysis). Scanian exhibits a pattern of diphthongization similar to that of Canadian French (§4.7), where the long vowels of other dialects of Swedish correspond to falling diphthongs in Scanian.

(43) *Scanian diphthongs*

/iː/	→	[ei]	/yː/	→	[øy]	/uː/	→	[eu]
/eː/	→	[ɛe]	/ʉː/	→	[øʉ]	/oː/	→	[ɛo]
/ɛː/	→	[æɛ]	/øː/	→	[œø]	/ɑː/	→	[æɑ]

Lindau's observation is that the first part of each diphthong is "one step lower" than the second part of the diphthong. In a theory where vowel height is captured by features like [high] and [low], this kind of lowering is problematic because (a) four vowel heights are required (e.g. {i e ɛ æ} for the front unrounded vowels), and (b) even if a feature like [low] is replaced by [mid] to allow four vowel heights, the lowering can only be expressed in a unitary fashion by invoking a paired variable notation between different features. In contrast, Lindau proposes a gradient [High] feature, with four values, 1–4, with a lower number constituting a higher vowel.[12] With such a gradient feature, the first part of the diphthong in Scanian can be straightforwardly characterized as "[n+1 high]" to the second part's "[n high]."

Clements (1990) discusses the gradient feature proposal, noting both advantages and problems. In its favor, the proposal removes the need inherent in a [high]/[low] theory of prohibiting the combination of *[+high, +low]. In addition, this theory reflects phonologically the phonetically n-ary nature of tongue raising/lowering (or alternatively, F1 lowering/raising). The theory also allows the direct characterization of vowel systems with four or more heights; this is an advantage if such systems are attested. And as already noted, this kind of gradient feature allows the expression of stepwise changes in vowel height, such as diphthongization in Scanian.

Problematic, however, are certain predictions of the gradient feature approach concerning natural classes. An example given by Clements is the predicted possibility of a rule mapping high and low vowels onto mid by a change that all vowels should become [2 high] adjacent to [2 high]. Another problem is how to autosegmentally treat partial assimilations (**Hayes 1990**), such as the raising of low to mid seen in Basque (§4.1.1). If assimilation is by spreading, then since the trigger of Basque assimilation is high ([1 high]), spreading should obligatorily produce complete agreement for height. That is, spreading from a high to a low vowel should obligatorily produce a high vowel, not the mid vowel actually observed in Basque.

In the following sections, various alternative ways of encoding scalar height will be examined. Proposals differ along two primary dimensions. First, some theories invoke monovalent height features while others invoke binary features. Second, a theory may postulate raising features, lowering features, or make both raising and lowering possible.

5.5.3 Monovalent open

Schane (1984) directly invokes an aperture feature, establishing the monovalent "particle" [a]. His approach to vowel specification involves the interplay between two "tonality" particles, [palatality] and [labiality], with an aperture particle indicating openness. The essential innovation is that a greater number of aperture particles indicates greater openness. For example, a seven-vowel inventory could be specified as follows:

(44) *Aperture as openness particles*

	Particles	
[i]	i	palatality
[ɪ]	ai	openness; palatality
[e]	aai	2 × openness; palatality
[a]	aa	2 × openness
[o]	aau	2 × openness; labiality
[ʊ]	au	openness; labiality
[u]	u	labiality

Although Schane does not discuss the role of [ATR], he explicitly proposes that the tense/lax distinction be built into the notion of aperture. An important consequence of the particle approach, which he notes, is that vowels that are phonetically similar might be specified in different ways in different languages depending on the system. For example, the particle specifications [ai] might constitute a lax high vowel [ɪ] in one language, and a mid vowel [e] in another; a low vowel [a] might have a single aperture particle in a language with a single central vowel but have two aperture particles in a language contrasting [ʌ] and [a] (the former specified as [a], the latter as [aa]).

While particle theory offers a straightforward account of one-step lowering cases, it has difficulty characterizing the class of high vowels, the class of mid vowels, the class of mid and high vowels, and so on; it also encounters various formal problems in the expression of assimilation rules. See **Elorrieta Puente (1996)**.

5.5.4 Monovalent closed

Parkinson (1996) proposes the mirror image of monovalent openness, namely a theory based on multiple specifications of monovalent [closed]. Like Schane's particle theory, vowel specifications differ depending on the number of vowel heights in the system, but it is the higher vowels that have more height specifications. For example, in a three-height system, high vowels would have two specifications for [closed], mid vowels would have one, low vowels would have none; in a four-height system, high vowels would have three specifications of [closed], high-mid vowels would have two specifications, low-mid vowels would have one and low vowels would again have none.

Parkinson's rationale for this feature reversal is based primarily upon the claim that all one-step shift harmonies involve raising, not lowering. Hence patterns such as Lena Spanish (§4.1.3) involve the addition of a [closed] feature. Since this theory is expressly designed to prevent one-step lowering, cases such as those in §4.2.3 and §4.7 warrant examination. While Parkinson does not discuss patterns such as Esimbi, he proposes an analysis of lowering diphthongization where one constraint prevents the addition of a [closed] particle (preventing raising) and a second constraint requires a height differential in the diphthong (thereby forcing lowering). Evaluating the proposed analysis depends crucially on assessing how a theory of height interacts with the overall structure of the rule or constraint system.

5.5.5 Ternary height and hierarchical height

An alternative to monovalency is the adoption of ternarity (**Elorrieta Puente 1996**; **Gnanadesikan 1997**). **Gnanadesikan (1997)** proposes that features like [high] and [low] be replaced by a ternary scale: high-mid-low. By allowing the specific penalizing of a shift between non-adjacent scale values, she is able to derive chain shift effects. Gnanadesikan's discussion of vowel height is a relatively small part of her overall discussion, hence she does not examine a full range of height issues. Since this proposal allows a maximum of three heights, the full range of height-related contrasts would require additional features such as [ATR].

In a rather different approach involving ternarity, **Elorrieta Puente (1996)** proposes the elimination of [ATR], and the adoption of a single, but hierarchically organized, height feature. Elorrieta Puente's proposal is for a [closed] feature with three values: [+1 closed] (the upper end of the height scale), [-1 closed] (the lower end) and [0 closed] (the midpoint). The proposal differs significantly from Gnanadesikan's, in that these three values may dominate an additional [closed] specification, where any of the three primary heights may dominate a two-way division into [+1 closed] or [-1 closed]. This provides for a maximum of six heights, and Elorrieta Puente proposes that this eliminates any requirement for the features [ATR] and [tense].

Elorrieta Puente's hierarchical proposal builds on earlier work by **Clements (1990, 1991)**. In Clements's conception of height, the overall vowel space dimension is successively divided into registers based on the binary feature [open]. A two-height system would therefore be defined by [+open] *vs.* [-open], where a three-height system would subdivide either of the primary registers into two sub-registers, and so on. With a focus on a wide variety of Bantu height systems, Clements argues that this hierarchical approach provides a unified account for step-wise raising and step-wise lowering as well as other types of vowel height phenomena. Clements too notes that this type of hierarchical organization would allow the elimination of a feature like [ATR].[13]

6 Conclusion

This discussion of vowel height has provided a sample of the phenomena that need to be treated in this domain, a sample emphasizing assimilatory patterns and ignoring completely certain patterns such as dissimilation.

All languages appear to distinguish at least some vowels by height, with some languages exhibiting quite complex patterns, particularly if tongue-root patterns are subsumed under vowel height. There has been a considerable amount of discussion concerning the representation of height features. While there is increasing agreement, though not consensus, that there should be a feature class corresponding to "height," there have been numerous proposals for how to characterize that class. Proposals include features like [high], [low], and [ATR]; monovalent, binary, and ternary features; features that are hierarchically structured; features of opening and of closing; and so on. There are also significant interactions between consonants and vowels, again with a wide range of treatments.

I close this chapter with a series of questions: Do "height" features always constitute a class, and if so, is the class definable phonetically? Should features like [ATR] be considered height features or place features? Should height features be the same for consonants and vowels? Do all languages behave the same way with regard to these features? Should the scalar behavior of some height systems be treated by adopting features that are neither binary nor monovalent? Or does the scalar behavior result from the way the constraint system interacts with the class of height features? How phonetically concrete are height features? Is their behavior abstract in interesting ways or concrete in ways that might be consistent with an emergent phonology?

These and other important issues concerning vowel height clearly require additional examination.

Notes

1 This may depend partly on how we define vowels, since various segments may be syllable nuclei without being vocalic.

2 **Jones (1972**: 32) refers to "acoustically equidistant vowels," but it is clear that he means vowels as perceived by a trained listener.

3 There is much more to be said about vowel height in Gunu (**Hyman 2001**).

4 Some of the examples exhibit an orthogonal process of fronting and rounding (**Pearce 2003**).

5 The rounding/fronting of the low vowel in certain examples is independent of the height (**Hyman 1988**).

6 The raised schwa represents a short transitional vowel that **Dettweiler (2000)** considers "non-phonemic," appearing in certain types of consonant clusters.

7 The k~g alternations observed in the Kikuria data are due to Dahl's Law, an unrelated pattern of voicing dissimilation. See, for example, **Davy and Nurse (1982)**.

8 Not relevant to the point under discussion, Efik also has the central vowel [ɨ] and Njebi also has the central vowel [ə].

9 The stem vowel [ə] undergoes fronting by an independent rule (**Clements 1990**).

10 As with [ə], the stem vowel [a] undergoes fronting by an independent rule (**Clements 1990**).

11 The feature [low] is parenthesized because **Odden (1991)** considers the evidence he presents to be inconclusive in this regard.

12 Lindau also uses the value [0 High] as a way of indicating glides.

13 See **Gick *et al.* (2006)** for an argument in favor of an ATR-based account for Kinande (Bantu; Democratic Republic of Congo).

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