11 Features and Contrast
B. Elan Dresher

1 Introduction

This chapter addresses two central and related concepts in phonological theory: features and contrast. Distinctive features are the entities into which phonological segments are decomposed; that is, they are the irreducible 'primes' of phonological representation.[1] As such, features are inherently contrastive, as one of their main functions is to show precisely how segments differ from each other. Nevertheless, although features convey contrast, there is a continuing tension between feature theory, which aims to be universal, and contrast, which is language particular. In this chapter we will review how this tension between the universal and the language particular has been addressed in phonological theory.

We will begin in section 2 by reviewing theories in which language-particular contrasts affect how features are assigned to segments. In section 3 we look at theories in which a universal system of features takes precedence over language-particular contrasts. Similar conflicts between the language particular and the universal arise with respect to theories of markedness, which have been invoked to complement the theory of features; therefore, section 4 reviews differing approaches to markedness. One source of evidence bearing on contrast, features, and markedness is their ability to account for why some vowel systems are common and others are rare; this is discussed in section 5. Section 6 takes up the question of how to determine which features are contrastive in any given phoneme. In section 7, we consider the scope of language-particular contrast: are contrasts evaluated once for the entire segmental inventory, or do there exist subdomains within inventories which are evaluated separately? Section 8 concludes the chapter.

2 Features as expressing language-particular contrasts

In their earliest manifestations in the work of the Prague School linguists Roman Jakobson and N. S. Trubetzkoy, distinctive features represent language-particular contrasts. What I mean by this is that segments that are phonetically 'the same' may receive different representations depending on what they contrast with. An early example of this approach is the analysis of two similar Slavic vowel systems by Jakobson ([1931] 1962), discussed in Dresher (2009: 3). Jakobson observed that with one exception, the simple vowels of Central Slovak 'correspond completely both in their production and in the auditive impression they produce to the vowels of Standard Czech'. The exception is an additional vowel /æ/ that occurs in Central Slovak that does not exist in Czech. Jakobson proposes that this additional vowel, 'though a mere detail from a phonetic point of view', affects the representation of every other Slovak short vowel, making them different from their

[1] This is what I will assume here, but it is an empirical hypothesis that the primes of phonology are binary features and not other sorts of entities, such as privative elements or dependency structures of various kinds; see van 't Veer et al. (2023) for a recent survey. I believe that many of the issues discussed in this chapter concerning features and contrast carry over, *mutatis mutandis*, to other conceptions of phonological primes.

Czech counterparts. Jakobson ([1931] 1962: 224) diagrams the Czech and Slovak short vowels as in (1).[2]

(1) Czech and Slovak vowel systems (Jakobson [1931] 1962: 224)

a. Standard Czech

i		u
e		o
	a	

b. Central Slovak

i	u
e	o
æ	a

In Central Slovak there is a contrast between the low vowels /æ/ and /a/: the former is more front (acute, in terms of Jakobson's features), and the latter is more back (grave). Jakobson assumes, presumably by symmetry, that this contrast holds also of the other vowels in Central Slovak, thereby creating a front /i, e, æ/ and a back /a, o, u/ series. In Standard Czech, the low vowel /a/ is not opposed to another low vowel, and Jakobson considers it to be neutral with respect to tonality (frontness/backness or rounding), having no contrastive value except for its height.

The status of the low vowel has consequences for the analysis of the other short vowels in Czech. Jakobson proposes that for those vowels, the two dimensions of frontness/backness (acuteness/gravity in Jakobson's terms) and roundness/non-roundness (flatness/non-flatness) form an 'indissoluble synthesis'; in other words, backness and roundness (similarly, frontness and lack of rounding) cannot be separated. Jakobson suggests that this explains why Czech speakers have difficulty pronouncing the German or French front rounded vowels, whereas Slovak speakers have little trouble with these sounds, despite not having front rounded vowels in their own language. He argues that the existence of a front/back contrast independently of lip rounding allows Slovak speakers to combine this dimension with rounding in a new way.

If we were to (anachronistically, and substituting feature names more currently in use) assign contemporary binary distinctive features to the vowels in (1) based on Jakobson's analysis, we might arrive at a table such as in (2). In Czech (2a), the vowel /a/ is specified only for [+low]. In Slovak (2b), the vowel /a/, which we are told corresponds completely to Czech /a/ in its phonetics, is also specified [+back], to distinguish it from /æ/. Therefore, this is a case of two vowels having identical phonetics but different feature specifications due to the presence or absence of other vowels in the inventory.

(2) Binary features for Czech and Slovak vowel systems based on Jakobson ([1931] 1962)

a. Standard Czech

	i	e	a	o	u
[low]	–	–	+	–	–
[bk/rd]	–	–		+	+
[high]	+	–		–	+

b. Central Slovak

	i	e	æ	a	o	u
[low]	–	–	+	+	–	–
[back]	–	–	–	+	+	+
[high]	+	–			–	+

The non-low vowels in Czech also differ in their features from their Slovak correspondents, despite their being phonetically identical. Whereas the Slovak non-low vowels have specifications

[2] I have inverted and reflected Jakobson's diagrams to the more familiar orientation of the vowel space with high vowels at the top and front vowels on the left. I use <æ> for Jakobson's <ä>.

for the feature [±back], in Czech there is no such feature. In Czech, according to Jakobson, backness cannot be disentangled from roundness, so vowels have a value for the feature [±back/round], which we could also call [±low F2].

This case is a clear example of how language-particular contrasts can affect the feature specifications of segments. This analysis is independent of whether we think that features are universal or not. Thus, let us suppose for the sake of argument that the features [back/round], [back], and [round] are all universal, available in principle to every language. Let us further assume for now that the feature [back/round] will be assigned to vowels that manifest a backness or roundness contrast unless there is evidence, as in Slovak, that only [back] (or in other cases, only [round]), is what is required. Even in this universal feature theory a segment's phonetics do not determine its phonological representation.

In the case of Czech and Slovak, the differing set of vowel contrasts in the two languages are associated with a difference in the number of vowel phonemes: five in Czech and six in Slovak. However, on the language-particular view of contrastive features, languages can differ in how they draw contrasts even when they have the same number of phonemes, and even when their phonemic inventories appear to be identical, a point made by Trubetzkoy (1939). In his discussion of five-vowel systems, he observes (1939: 90–91) that in Latin, as in many such systems, the low vowel does not participate in tonality contrasts, but is contrastive only with respect to height. Thus, the Latin vowel system has the same analysis as Standard Czech in (2a).

But, according to Trubetzkoy, this is not true of all five-vowel systems that can be represented as /i, e, a, o, u/. In Archi (East Caucasian), a language of Central Daghestan, a consonantal rounding contrast is neutralized before and after the rounded vowels /u/ and /o/. 'As a result, these vowels are placed in opposition with…unrounded *a, e,* and *i*' (Trubetzkoy 1969: 100–101).[3] In Japanese, Trubetzkoy argues that neutralization of the opposition between palatalized and non-palatalized consonants before /i/ and /e/ shows that these vowels are put into opposition with the other vowels /a, o, u/ (Trubetzkoy 1939: 92). Though Trubetzkoy does not give a complete analysis of these vowel systems, his discussion is consistent with the feature assignments in (3) (the Japanese features are adapted from Hirayama 2003).

(3) Binary features for Archi and Japanese vowel systems based on Trubetzkoy (1939)

a. Archi

	i	e	a	o	u
[low]		–	+		
[round]	–	–	–	+	+
[high]	+	–	–	–	+

b. Japanese

	i	e	a	o	u
[low]			+	–	
[back]	–	–	+	+	+
[high]	+	–	–	–	+

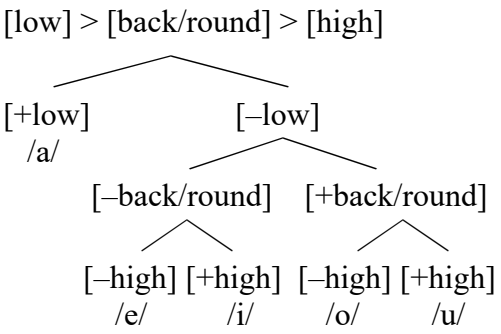
Even if we assume that the corresponding vowels in Czech, Archi, and Japanese are phonetically more or less the same, and even if we assume that the features [low], [high], [round], and [back] are universal, the contrastive representations of the three vowel systems are different. This is most obvious in the case of /a/, which we assume to be [+low] in all three systems but which differs in its tonality feature: none in Czech, [–round] in Archi, and [+back] in Japanese. Other vowels also have varying representations. In Czech, all the other vowels contrast with /a/ in being [–low], whereas in Archi only /e/ is contrastively [–low], and in Japanese only /o/ is.

[3] English translations of Trubetzkoy (1939) are from Trubetzkoy (1969).

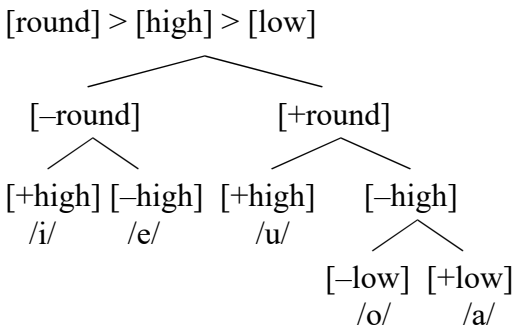
Building on later work by Jakobson and his colleagues (Jakobson 1941; Jakobson & Lotz 1949; Jakobson, Fant, & Halle 1952; Cherry, Halle, & Jakobson 1953; Jakobson & Halle 1956; Halle 1959; see Dresher 2016 for a history), these differing contrastive relations can be generated by branching trees as in (4), where features are assigned in a language-particular order until every segment has a unique representation ('>' means 'is assigned before').

(4) Five-vowel systems, different ordering of contrastive features

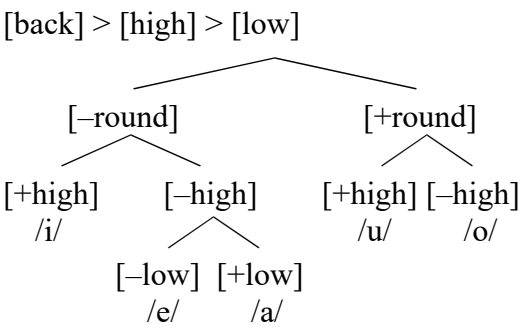
a. Czech/Latin



b. Archi



c. Japanese



A version of this approach was revived by Clements (2001; 2003; 2009), and independently at the University of Toronto, under the name Modified Contrastive Specification and later Contrastive Hierarchy Theory (Dresher, Piggott, & Rice 1994; Dyck 1995; Zhang 1996; Dresher 1998, 2009; Hall 2007; Mackenzie 2013; Dresher, Harvey, & Oxford 2018; etc.).

3 Features as expressing universal contrasts

In opposition to a theory such as the one above, there exist theories of phonological representation in which language-particular contrasts do not influence feature specifications to the same degree. An example of this type of theory is the one proposed in Chomsky & Halle (1968; *The Sound Pattern of English,* henceforth SPE). SPE proposes that phonological features are universal and have relatively fixed phonetic correlates. For example, SPE defines the features [back] and [round] as in (5).

(5) Definitions of [back] and [round] in SPE (Chomsky & Halle 1968: 305–309)
   a. Back sounds are produced by retracting the body of the tongue from the neutral position; nonback sounds are produced without such a retraction from the neutral position.
   b. Rounded sounds are produced with a narrowing of the lip orifice; nonrounded sounds are produced without such a narrowing.

In the SPE theory, language-particular contrasts do not influence the assignment of feature specifications to segments, and the Czech and Slovak vowels in (1) would be partially specified in terms of the same universal set of features, as in (6a) and (6b), respectively. Thus, the lone low vowel /a/ of Czech has the same specifications as the Slovak /a/, and all the vowels are fully specified for all of [low], [high], [back], and [round].[4] By the same token, every five-vowel system that resembles Czech, such as Latin, Archi, and Japanese, will be assigned the same feature values.

(6) Binary features for five-vowel systems based on Chomsky & Halle (1968)

a. Standard Czech, Latin, Archi, Japanese, etc.

	i	e	a	o	u
[low]	–	–	+	–	–
[back]	–	–	+	+	+
[round]	–	–	–	+	+
[high]	+	–	–	–	+

b. Central Slovak

	i	e	æ	a	o	u
[low]	–	–	+	+	–	–
[back]	–	–	–	+	+	+
[round]	–	–	–	–	+	+
[high]	+	–	–	–	–	+

A more recent version of a universal feature theory is proposed by Duanmu (2016). As he writes in the Preface (2016: ix): 'The goal of this study is to determine a feature system that is minimally sufficient to distinguish all consonants and vowels in the world's languages.' His study is guided by a criterion of universal contrast: two sounds are considered distinct only if they contrast in some language. In this way he abstracts away from phonetic variation that is never contrastive in a language. Through a rather ruthless series of reanalyses, Duanmu argues that no known language has more than the sixteen basic vowels shown in (7) (these do not include length distinctions or non-basic vowels, such as nasalized, breathy, creaky, and retroflex vowels, which require additional features). The vowels in (7) require four features, each one attached to an articulator: [round] (lips), [high] and [back] (tongue body), and [advanced = ATR] (tongue root).

(7) Basic vowels: Universal two-height system with four features (Duanmu 2016: 54)

		[–back]		[+back]	
		[–round]	[+round]	[–round]	[+round]
[+high]	[+ATR]	i	y	ɯ	u
	[–ATR]	ɪ	ʏ	ʌ	ʊ
[–high]	[+ATR]	e	ø	ɜ	o
	[–ATR]	ɛ	œ	ɑ	ɔ

[4] This discussion is limited to the features we have been discussing; in SPE vowels are specified for other features such as [anterior], [coronal], [tense], etc., but these are not relevant here.

Duanmu (2016) writes that this theory is based mainly on contrast and does not take into account the way sounds pattern. Therefore, there is no place in this theory for assigning varying representations to the five-vowel systems discussed above; rather, all systems with the vowel phonemes /i, e, a, o, u/ would be represented as in (8).

(8) Binary features for a five-vowel system based on Duanmu (2016)

	i	e	a	o	u
[back]	–	–	+	+	+
[round]	–	–	–	+	+
[high]	+	–	–	–	+
[ATR]	+	+	–	+	+

It is worth noting that fitting every vowel system in the world into this highly restricted set of universal features requires 'some degree of underspecification' (Duanmu 2016: 108), as well as a certain flexibility in the mapping between phonology and phonetics. Thus, no vowel system can have more than two height classes according to (7), even if phonetically there are common vowel systems that have more height distinctions than that. We have seen, for example, that many five-vowel systems have been commonly analyzed as having three height classes: high (/i, u/), mid (/e, o/), and low (/a/). The question is whether a universal feature theory like that in (7) still allows for insightful analyses into phonological patterning.

4 Markedness and contrast

At different times one or the other approaches discussed above has been dominant in phonological theory. Roughly speaking, in the structuralist and early generativist periods from the 1920s to the 1950s the former, contrastivist, approach was influential; after 1968 it was replaced within generative phonology by the universalist approach for the rest of the century. Arguments against universal features became influential in the 2000s; for example, Mielke (2008) and Samuels (2011) argued that phonological features are not innate, but rather 'emerge' in the course of acquisition. If individual features are not innate, there must still be some set of principles that guide learners in constructing features for their language, a universal feature theory without universal features (Dresher 2014). If there is no universal set of features, there can be no such thing as 'full specification'; in such a theory, it would appear that contrast would again play an important role in guiding the acquisition of phonological representations.

At bottom the issue of how much cross-linguistic variation there is is an empirical one. Jakobson's analysis of Czech, for example, predicts that we should not find /a/ patterning together with /u/ and /o/ as a [+back] class.[5] Nor should we find /o, u/ triggering a rounding rule in which the feature [round] had to be dissociated from [back]. In the SPE-style analysis, no such predictions

[5] This prediction has some nuances. There could, for example, be a rule in Czech triggered by /i, e/ (e.g., certain consonants might be affected in a certain way in the vicinity of a [–back/round] vowel); in that case, it would *look* like /a/ was patterning with /u, o/ in not triggering the rule. But this kind of negative class doesn't count; a genuine counterexample would be a rule positively triggered by /a, o, u/ acting as a class because they share a triggering feature.

are made. On the other hand, a universalist theory predicts that phonetically similar segments in different languages should pattern phonologically in similar ways, whereas a contrastivist theory predicts that phonetically similar segments may behave very differently in the phonology.

4.1 SPE: Universal markedness to supplement universal features

There were already indications in SPE that there is a price to be paid for disregarding language-particular contrasts, though SPE does not put it that way. Chomsky & Halle (1968: 400) open Chapter 9 with a dramatic statement: 'The entire discussion of phonology in this book suffers from a fundamental theoretical inadequacy.' This inadequacy consists of SPE's 'overly formal' approach to features, which does not take into account their intrinsic content. If all segments are fully specified in terms of the same features, and the evaluation measure counts only the number of symbols, then there is no basis for evaluating any segment as being more or less costly, or complex, than any other. As a result, the SPE theory as presented in the first eight chapters could not account for why certain segments are more common than others, and why certain segmental inventories are common and others are not.

A related inadequacy concerns incorrect predictions about which phonological rules should be considered more highly valued. One example concerns the pair of rules shown in (9). Chomsky & Halle observe that a rule changing /i/ to [u] is cross-linguistically more common than a rule changing /i/ to [ɨ]. However, their evaluation measure, which assigns higher values to rules that utilize fewer features, makes the wrong prediction: in terms of features, a rule changing /i/ to [u] must change two features, as in (9a), whereas /i/ to [ɨ] requires a change of only one feature (9b).

(9) Two rules that change /i/ to [+back] (Chomsky & Halle 1968: 401)

a. /i/ → [u]

$$\begin{bmatrix} \text{V} \\ \text{–low} \\ \text{+high} \\ \text{–back} \\ \text{–round} \end{bmatrix} \rightarrow \begin{bmatrix} \text{+back} \\ \text{+round} \end{bmatrix}$$

b. /i/ → [ɨ]

$$\begin{bmatrix} \text{V} \\ \text{–low} \\ \text{+high} \\ \text{–back} \\ \text{–round} \end{bmatrix} \rightarrow \text{[+back]}$$

To remedy this shortcoming in the theory, Chomsky & Halle propose to introduce a version of markedness theory which assigns universal markedness values to segments. These values are arrived at by a series of markedness conventions that stipulate what the unmarked values of features are in various contexts; for example, in the context of [–low], the unmarked value of [round] is the same as the value of [back] (10bi). That is, the unmarked value for round is [–round] for a front non-low vowel, and [+round] for a back non-low vowel. These markedness conventions follow a universal feature hierarchy. With respect to this example, the hierarchy is [low] > [back] > [round]. This is because the markedness values of [back] are sensitive to the value of [low] (10a), and the markedness values of [round] depend on [back] as well as [low] (10b), suggesting that they need to be assigned in that order.

(10) Markedness conventions for features [back] and [round] (Chomsky & Halle 1968: 405)

a. Convention X: [u back] → $[+\text{back}]/\left[\frac{\quad}{+\text{low}}\right]$

b. Convention XI: [u round] → $\left\{\begin{array}{ll}[\alpha\text{round}]\ /\left[\begin{array}{c}\overline{\quad\alpha\text{back}\quad}\\ -\text{low}\end{array}\right] & \text{(i)}\\ [-\text{round}]\ /\left[\frac{\quad}{+\text{low}}\right] & \text{(ii)}\end{array}\right.$

Taking into account all the markedness conventions for vowels, Chomsky & Halle (1968: 409) arrive at the table in (11), where the complexity of a vowel is its total markedness score. For example, /u/ is assigned a complexity value of 1, and /ɨ/ is assigned the value 2, meaning that /u/ is a less marked (i.e., less costly) vowel than /ɨ/.[6]

(11) Markedness matrices for vowels (Chomsky & Halle 1968: 409)

	a	i	u	æ	ɒ	e	o	y	ɨ	œ	ø	ʌ
low	u	u	u	m	m	u	u	u	u	m	u	u
high	u	u	u	u	u	m	m	u	u	u	m	m
back	u	−	+	m	u	−	+	−	+	m	−	+
round	u	u	u	u	m	u	u	m	m	m	m	m
Complexity	0	1	1	2	2	2	2	2	2	3	3	3

To complete the solution to the problem of rules like (9), Chomsky & Halle propose to allow the markedness conventions to play a role in the rule system by means of the concept of *linking*. The basic idea (see Dresher 2009: 104–117 for a more detailed discussion) is that when a feature is changed by a rule, all the features below it in the hierarchy revert to their unmarked value. In the case of the rule changing /i/ to [u] in (9a), it is now no longer necessary to specify the change in [round]. It is sufficient to explicitly change only [back]; since [round] is lower in the markedness hierarchy than [back], when [–back] changes to [+back], linking forces [round] to take on its unmarked value in the new context [–low, –back], which is [+round] according to (10bi). Conversely, if we want /i/ to change to [ɨ] as in (9b), we must prevent the linking of the markedness convention for [round] by explicitly specifying that the output must be [–round]. We have now made the rule changing /i/ to [u] less costly than the one changing /i/ to [ɨ]. This analysis is summarized in (12).

[6] The SPE markedness theory was revised and streamlined by Kean (1980), who arrives at slightly different complexity values.

(12) Two rules that change /i/ to [+back] with linking (Chomsky & Halle 1968: 423)

	a. /i/ → [u]	b. /i/ → [ɨ]
Target	[V, –low, +high, –back, –round]	[V, –low, +high, –back, –round]
Change	[+back]	[+back, –round]
Linking	[round] becomes [+round]	Does not apply
Result	[u]	[ɨ]

4.2 An alternative to universal markedness based on language-particular feature contrasts

The SPE solution is based on the idea that [u] is universally less marked than [ɨ], and that by building this fact into the markedness system the relative costs of the rules in (9) can be corrected to that of (12). This solution does not accord any role to language-particular contrast. However, there exists an alternative solution that does rely on such contrast. Before turning to that, I would like to delve a bit further into the key notion that [u] is universally less marked than [ɨ]. This claim is motivated by the observation that [u] is a very common segment that can be found in the vowel systems of many languages, whereas [ɨ] is much less widely distributed. For example, the online phonological inventory PHOIBLE (Moran & McCloy 2019) lists [u] as occurring in 2,646 inventories, or 88% of all inventories listed, whereas [ɨ] is reported in 491 (16%) inventories.[7]

An apparently paradoxical fact has been observed, however: when /u/ and /ɨ/ both occur together in an inventory, /ɨ/ acts as if it is less marked than /u/ by many common criteria (Rice 2003, 2007). Thus, Rice (2007: 92) observes that when there is a contrast in vowel place between front, central, and back, it is the central place that is usually the least marked. Similarly, when there is a place contrast between a front and a central vowel, say /i/ and /ɨ/, respectively, it is again the central place that is unmarked, even though [i], which occurs in 2,779 (92%) inventories in PHOIBLE, is much more cross-linguistically common than [ɨ].

This paradox suggests that the claim that [u] is universally less marked than [ɨ] needs some rethinking, and indeed, a different perspective on this issue in terms of language-particular contrast is able to resolve the paradox. First, there is an argument that suggests that contrast is a crucial piece of the /i/-to-[u/ɨ] problem. For while it is certainly the case that a rule that adds a [+back] feature to /i/ much more commonly results in [u] than in [ɨ], this result holds true only when the inventory contains a /u/ and no distinct /ɨ/. When the language has a phoneme /ɨ/ in contrast with /u/ and /i/, adding [+back] to /i/ results in [ɨ], not [u]. An example can be found in Tuvan (Turkic), whose vowel system is shown as in (13).

[7] Although in this case we can be confident that [u] is cross-linguistically more common than [ɨ], statistics reported by PHOIBLE should be viewed with skepticism, because there is a certain arbitrariness in the way that segments are reported. For example, many three-vowel inventories are reported as containing [i, a, u], even though each vowel phoneme may have several phonetic realizations depending on context. Also, PHOIBLE does not distinguish between inventories where [ɨ] and [i] are allophones of a single phoneme and those in which [ɨ] is a member of a phoneme that is distinct from /i/. See Dresher & Rice (2015) and Dresher, Hall, & Mackenzie (2021) for discussion and examples.

(13) Tuvan vowel system (Anderson & Harrison 1999; Rose & Walker 2011)

	Front		*Back*	
	Non-round	*Round*	*Non-round*	*Round*
High	i	y	ɯ	u
Non-high	e	ø	a	o

As shown in (14), suffixes harmonize in backness with the stem vowel. When the stem vowel are [–back] (14a, c), the suffix vowels are [i] and [e]; when the stem vowels are [+back] (14b, d), the suffix vowels are [ɯ] and [a]. That is, the front non-round [e] alternates with back non-round [a] and front non-round [i] alternates with back non-round [ɯ]. Here, there is no intervention of linking to turn [ɯ] into the supposedly less marked [u], presumably because /ɯ/ exists as a separate contrastive phoneme in the inventory.

(14) Tuvan backness vowel harmony (Rose & Walker 2011: 252)

a. is-ter-im-den ‘footprint-PL-1-ABL’
b. at-tar-ɯm-dan ‘name PL-1-ABL’
c. esker-be-di-m ‘notice-NEG-PST.II-1’
d. udu-va-dɯ-m ‘sleep-NEG-PST.II-1’

Rose & Walker (2011: 252) note further that epenthetic vowels in word-medial syllables of disharmonic Russian loan words harmonize in backness with a preceding vowel; the examples they cite (15) are *texina:r* ‘grain alcohol’ and *partɯfel* ‘wallet’ (epenthetic vowels are underlined). Assuming that the epenthetic vowel is either /i/ or a high vowel unspecified for backness, linking again does not intervene in (15b) to change it to [u] when it becomes [+back].

(15) Tuvan epenthesis (Rose & Walker 2011: 252)

a. tex<u>i</u>na:r ‘grain alcohol’
b. part<u>ɯ</u>fel ‘wallet’

As an alternative to the SPE universal markedness solution to the /i/-to-[u/ɨ] problem, let us consider how the analysis would go if we took an approach similar to Jakobson’s ([1931] 1962) account of the Czech and Slovak vowel systems. Suppose that a language like Slovak, with the features of (2b), repeated here as (16a), had a rule changing /i/ to [+back]. The result would be a vowel with the features [–low, +back, +high]; but these are exactly the features of /u/! Somehow we obtain the desired result without any further mechanisms like universal markedness or linking conventions. It is worth looking a bit deeper into how this result was achieved.

(16) Changing /i/ to [+back] in a Jakobson-style analysis

a. A language like Slovak

	/i/	/e/	/æ/	/a/	/o/	/u/
[low]	–	–	+	+	–	–
[back]	–	–	–	+	+	+
[high]	+	–			–	+

b. Change /i/ to [+back]

/i/				/u/
–		–		–
–	→	+	=	+
+		+		+

The key to the result in (16) is that the segments are underspecified; in particular, the feature [round] does not appear in (16) at all. The specification of the segment /u/, [–low, +back, +high], does not indicate that /u/ is round; indeed, this specification is compatible not just with [u], but

also with central-back unrounded [ɨ], back unrounded [ɯ], and a retracted tongue-root vowel [ʊ]. The feature system of (16) does not distinguish between these vowels. The same is true of all the other vowels: in the absence of values for the feature [round], we cannot know, simply from looking at the feature values in (16a), whether any of the vowels are rounded or not. The first four vowels in (16a) are transcribed as unrounded /i, e, æ, a/, but it would be equally consistent with the given features if they were all rounded /y, ø, œ, ɒ/; similarly, /o/ could be unrounded /ɤ/.

At this point, then, it is not entirely correct to say that the result of changing [–back] to [+back] in /i/ in (16) is [u], since we do not know the value of [round] and other unspecified features for the vowel we are calling /u/. What we can say, however, is that the result of changing [–back] to [+back] in /i/ results in a vowel that is not featurally different from /u/. In order to obtain a new vowel (i.e., a vowel that is not already in the inventory) like [ɨ] we would have to add features that are not included in (16); in this case, we would have to add [–round] to distinguish [ɨ] from [u], which would itself have to be supplemented with [+round]. In this way, underspecified features do the work of the markedness conventions and linking in SPE; indeed, linking itself works by temporarily underspecifying certain features before filling them in again.

5 Accounting for common vowel systems

Are we, then, justified to designate the vowel in the final column of (16) as /u/ rather than as /ɨ/ or any of the other vowels consistent with the features [–low, +back, +high]? Any phonological theory that allows or requires underspecified representations must be supplemented by principles that specify those properties of a segment that are unspecified but which are necessary for production and perception. Thus, a vowel must be pronounced with or without lip rounding, and with or without advancement or retraction of the tongue root, and so on. Even a theory of full specification such as SPE must supplement its binary features with finer-valued phonetic features to indicate degrees of lip rounding, nasalization, etc.

We have seen that in order to account for why some segments are cross-linguistically more common than others, SPE proposes a universal markedness theory that assigns segments varying degrees of complexity, with the least complex segments predicted to be the most commonly found.

Another proposal for why some vowel systems are more common than others is Dispersion Theory, proposed by Liljencrants & Lindblom (1972) and elaborated by Lindblom (1986), and adapted to constraint-based Optimality Theory by Flemming (2002), Padgett (2003a,b), and Sanders (2003). The basic idea is that phonological inventories exhibit a tendency to maximize auditory distinctiveness. Thus, in the three-vowel system /i, a, u/, the vowels are maximally dispersed to the corners of the auditory space; the unattested three-vowel system /ɨ, ə, ʉ/ is very poorly dispersed.

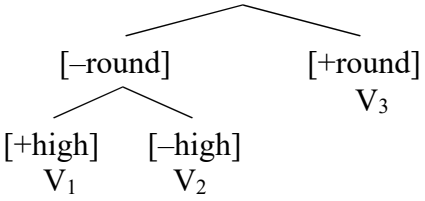
Hall (2011) argues that Dispersion Theory depends on placing vowels in particular starting points, and that some choices of starting points can result in implausible vowel inventories. He proposes instead that common vowel systems result from phonologically unspecified features combined with the enhancement theory of Stevens, Keyser, & Kawasaki (1986). They propose that feature contrasts can be *enhanced* by other features with similar acoustic effects (see also Stevens and Keyser 1989; Keyser and Stevens 2001, 2006). Thus, a vowel that is contrastively [+back] (low F2) can be enhanced by adding {+round}, which further lowers F2; a vowel that is [–low] can enhance this feature by adding {+high}. I indicate enhancement features by curly brackets {}, and leave open whether these are truly features of the same kind as contrastive phonological features. Enhancements are not universal, and other realizations are possible (Dyck

1995; Hall 2011); nevertheless, they represent the common ways that phonological representations can be elaborated.

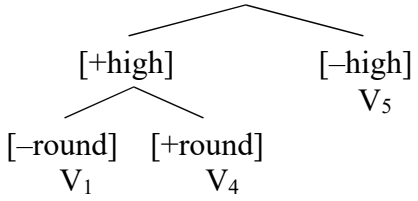
Contrastive underspecification plays a key role in Hall's (2011) approach: only as many features are permitted as are needed to distinguish between all the members of an inventory. Thus, for a three-vowel inventory, only two features may be specified. Suppose we pick the features [±round] and [±high]. In a hierarchical approach to contrastive specification, these features can be assigned in two different orders: [round] > [high], or [high] > [round]. These options are shown in (17). The vowels in (17) are indicated schematically only as V_n; some possible realizations for each vowel are listed in (18).

(17) Two ways of generating a three-vowel system with [round] and [high]

a. [round] > [high]



b. [high] > [round]



(18) Some values for the vowels in (17)

a. [round] > [high]

V_1	V_2	V_3
[–rnd, +hi]	[–rnd, –hi]	[+rnd]
[i, ɨ, ɯ]	[e, ə, ɐ, ʌ æ, a, ɤ]	[y, u, ʊ, ø, ɔ]

b. [high] > [round]

V_1	V_4	V_5
[+hi, –rnd]	[+hi, +rnd]	[–hi]
[i, ɨ, ɯ]	[y, ʉ, u, ʊ]	[e, ə, ɐ, a, ɤ, ʌ, ø, o, œ, ɔ, ɒ]

The various speech sounds shown in (18) are all theoretically possible phonetic realizations of the vowels generated by (17). However, some are more likely than others given the workings of enhancement, as well as other possible constraints on production and perception. In this case, common enhancements are shown in (19), yielding [i, a, u] as the most likely realizations.

(19) Common enhancements of the vowels in (17) and (18)

a. V_1: [–round] is commonly enhanced by {–back} in a non-low vowel, leaving [i, ɨ], and [+high] is enhanced by {+ATR}, yielding [i].
b. V_2, V_5: [–high] can be enhanced by {+low}, which excludes the non-low vowels; in the absence of pressure to be specifically front, back, or round, we are left with [a].
c. V_3, V_4: The features [+high, +round] (V_4) are most commonly enhanced by {+back} and {+ATR}, yielding [u]. V_4 is just [+round]; in the absence of [+low], it too can be enhanced by {+back} and end up as [u], though other outcomes cannot be excluded.

6 Determining which features are contrastive

In a theory that assumes that features are universal and that segments are fully specified for every feature that applies to them, it is not necessary to distinguish between contrastive and non-

contrastive specifications. However, in theories that posit that only contrastive features are assigned, it is necessary to have a way of determining which features are contrastive for each phoneme.

We have already seen one method for computing contrastive features, the one posited by Contrastive Hierarchy Theory, building on the work of Jakobson, Halle, and their colleagues: features are assigned according to the successive Division Algorithm (SDA), given in a simplified version in (20) (a more detailed procedural formulation is given in Dresher 2009: 16).

(20) The Successive Division Algorithm (Dresher 1998, 2003, 2009)
Assign contrastive features by successively dividing the inventory until every phoneme has been distinguished.

There is another commonly adopted approach in which features are designated as contrastive only if they serve to minimally distinguish otherwise identical pairs of segments (e.g. Padgett 2003a,b; Calabrese 2005; Campos-Astorkiza 2009; Nevins 2010), as in the formulation in (21).

(21) The Minimal Difference approach to contrast (Nevins 2010: 98)
A segment S with specification [αF] is *contrastive* for F if there is another segment S′ in the inventory that is featurally identical to S, except that it is [–αF].

In what can be called the Minimal Difference approach, contrast is evaluated over segment pairs and there is only one possible set of contrastive specifications for a given inventory. When applied to a typical five-vowel inventory, this approach looks reasonable enough when we start with three features, as in (22a). Here, the members of the pairs /i, e/ and /u, o/ are uniquely distinguished from each other by [±high], so this feature must be contrastive on these phonemes. Similarly, /i, u/ and /e, o/ are each distinguished by [±back]. The feature [±low] is the sole feature that distinguishes /a/ from /o/, but does not minimally distinguish /i, e, u/ from any other phoneme.

(22) Minimal Difference: contrastive feature specifications for a five-vowel inventory

a. Starting with three features

i. Full specification

	i	e	a	o	u
[low]	–	–	+	–	–
[back]	–	–	+	+	+
[high]	+	–	–	–	+

ii. Contrastive specifications

	i	e	a	o	u
[low]			+	–	
[back]	–	–		+	+
[high]	+	–		–	+

b. Starting with four features

i. Full specification

	i	e	a	o	u
[low]	–	–	+	–	–
[back]	–	–	+	+	+
[high]	+	–	–	–	+
[round]	–	–	–	+	+

ii. Contrastive specifications

	i	e	a	o	u
[low]					
[back]					
[high]	+	–		–	+
[round]					

However, if we add one more feature, such as [round], as in (22b), we obtain no usable results. The problem is that [back] and [round] do much the same contrastive work; therefore, [back] no longer uniquely distinguishes /i, u/ and /e, o/, and neither does [round]. [high] is still contrastive for /i, e/ and /u, o/, but [low] is no longer contrastive for any segment, including /a/. Despite /a/ being the only [+low] member of this inventory, it does not uniquely distinguish /a/ from any other vowel, because no other vowel has the combination [+back, –round].

This problem with Minimal Difference was pointed out by Archangeli (1988) and in more detail by Dresher (2009: 19–28). Unless supplemented by additional principles (see Dresher 2009: 28–29), Minimal Difference is not guaranteed to give a coherent result for any arbitrary inventory and set of features. On the other hand, a hierarchical approach using the SDA is guaranteed to yield a set of contrastive specifications, as long as there are enough features to distinguish all the members of the inventory. Therefore, I believe that Halle (1959: 32) was correct in arguing that a hierarchical approach is the only way to correctly derive contrastive feature specifications.

Unlike Minimal Difference, a hierarchical approach yields different results depending on how the features are ordered, as was demonstrated in (4). But even theories that adopt some version of a feature hierarchy can differ in how much cross-linguistic variation they allow. Jakobson & Halle (1956), for example, propose that there is a universal order, with some minor variations, in which children acquire feature contrasts. Subsequent empirical studies suggest that their theory is overly restrictive; see Menn & Vihman (2011) for a review, and Bohn (2015, 2017) for a study of the acquisition of the Brazilian Portuguese vowel feature hierarchy.

Clements (2001) proposed that features are ordered into an Accessibility Hierarchy, later revised as the Robustness Hierarchy (Clements 2009). Clements (2001: 79) writes that 'features can be ranked according to a universal hierarchy of accessibility', which limits the degree to which feature hierarchies can vary. The FUL (Featurally Underspecified Lexicon) model of Lahiri & Reetz (2002) and the Radical CV Phonology of van der Hulst (2020) both assume hierarchically structured features that have some degree of universal ordering.

Dresher (2015) shows that several criteria have been appealed to as determining how to order features into a hierarchy. Universality (having a universal hierarchy) has competed with minimality (ordering the features so as to minimize the number of feature specifications). Contrastive Hierarchy Theory has prioritized the principle of phonological *activity*, that is, the way sounds pattern in a particular language. Activity can be defined as in (23).

(23) Phonological activity (adapted from Clements 2001: 77)
A feature can be said to be *active* if it plays a role in the phonological computation; that is, if it is required for the expression of phonological regularities in a language, including both static phonotactic patterns and patterns of alternation.

It is ultimately an empirical question to what extent feature hierarchies can vary across languages, and how the various competing criteria should be weighted.

7 The scope of language-particular contrast: contrast limited by position

In considering the way features express language-particular contrasts, up to here we have assumed that the contrastive specifications of each phoneme are evaluated once for the entire language; for example, the feature hierarchies in (4) for Czech/Latin, Archi, and Japanese, respectively, specify the features for each vowel, no matter where it occurs in an utterance. However, there have been

proposals that the domain over which contrasts are defined is not the whole language, but is limited to certain positions. That is, a single segment in one language might have several different contrastive specifications, depending on the context in which it appears. In this section I will briefly review some of these proposals.

7.1 Twaddell (1935) and Martinet (1964)

Twaddell (1935) proposes a procedure for identifying phonemes based on minimal contrasts within words.[8] For example, he proposes that we can identify a word-initial series of contrasts as in (24a). The initial consonants /p, t, k/ differ with respect to place of articulation, and have in common that they are all aspirated, voiceless, and exploded (released) stops. The fourth member of this series, /b/, is contrastively bilabial, unaspirated, voiced, and an exploded stop. Twaddell (1935: 48) refers to this set of ordered terms as 'micro-phonemes'. Similarly, we can identify a word-final series (24b) of micro-phonemes which have a similar set of place and voicing contrasts, but differ from (a) in that they are all unaspirated and unexploded (unreleased) stops. We can then align the two sets as having the common contrastive features in (24c). Twaddell refers to the sum of all similarly ordered micro-phonemes as 'macro-phonemes'.

(24) Identifying phonemes based on minimal contrasts (Twaddell 1935)

a. Initials	b. Finals	c. Common contrastive features
pill	na**p**	bilabial; voiceless
till	gna**t**	alveolar; voiceless
kill	na**ck**	palatovelar; voiceless
Bill	na**b**	bilabial; voiced

Because the initials and finals in (24) are similarly ordered, they can be grouped into macro-phonemes, despite certain phonetic differences; that is, initial [p^h] and final [$p^\neg$] can be combined into a single (macro-)phoneme /p/. The same is not the case for [p] that follows /s/, however, because a contrast between /p/ and /b/ does not exist in this position (25).

(25) Series of stops following /s/

s**p**ill, s**t**ill, s**k**ill, *s**b**ill

Twadell (1935: 49) concludes, 'There appears to be no alternative to considering the stops of 'spill, spare, spin', etc. as corresponding to a different phoneme from the stops of 'pill, pare, nap, lip, tapper, slapper', etc.'

It remains controversial as to whether [p, t, k] after /s/ should be considered to be allophones of /p, t, k/ (if the main contrasting feature is considered to be [–voice]), or of /b, d, g/ (if the contrasting feature is [–aspirated]), or separate phonemes, as proposed by Twaddell. In other cases, however, Twaddell's procedure is vulnerable to what appear to be accidental gaps. For example, the [p^h] in *pig* cannot be united into the same phoneme as the [p^h] in *pill* because the words **tig*

[8] For a more detailed discussion see Dresher (2009: 59–60).

and **kig* do not exist. Twaddell (1935, 50–51) considers this to be an undesirable result which needs to be remedied.

A similar procedure is proposed by Martinet in arriving at the contrastive specifications of the phonemes of Franco-Provençal of Hauteville (Martinet 1956) and of Standard French (Martinet 1964). Similarly to Twaddell (1935), Martinet (1964: 62–64) begins his analysis of the French consonants by listing all the consonants that appear before *-ouche* (e.g., *douche, souche, touche*, etc.). Martinet, however, loosens the criterion by also including consonants that *may* appear in that context, even though there is no current French word with that sequence.

7.2 Polysystematicity

The strategy of identifying contrastive phonemes by position is taken further in the Glossematics linguistic theory associated with the Danish linguists Louis Hjelmslev and Hans Jørgen Uldall (Basbøll 2022), and in Firthian Prosodic Analysis (FPA), developed by colleagues of the British linguist J. R. Firth. As explained by Battaner Moro and Ogden (2022: 255):

> FPA ... is polysystemic: that is, it establishes multiple systems of contrast which hold at different places in phonological structure, and does not assert any necessary identity of elements in different systems. For example, if a syllable-initial system contains the elements *w, y*, and *h* but a syllable-final system contains the elements *h* and non-*h*, the two *h* units are not considered identical because they contrast with different terms, and different numbers of terms.

The notion that phonemes enter into several co-existing system of contrasts is carried on in Dependency Phonology (Anderson and Jones 1974; Anderson and Ewen 1987; see Staun 2022 for an overview). For example, Anderson (2005) observes that the prenasal short vowel system in early Old English had fewer contrasts than in other positions: there were only three contrasting stem vowels before nasals (e.g., *bind, band, bund*) as opposed to five or six in other positions (*i, e, a, (æ), o, u*). He proposes that the prenasal vowels form a separate subsystem with potentially distinct representations. In his words (Anderson 2005: 208), 'members from different subsystems (just as from different languages) may share exponence [phonetic realization/BED] but differ in their lexical/contrastive representations.'

Dresher (2009: 190) suggests that some conditions have to be met in order to set up a separate contrastive subdomain. First, the phonemes in the subdomain must not have alternants in another domain. For example, an English coda consonant, such as the final [t˺] in *write,* can become an onset [ɾ] when a suffix is added, as in *writer*. Presumably the stem *write* has a single underlying representation; therefore, the coda [t˺] and onset [ɾ] must derive from a common underlying phoneme /t/, and cannot be part of separate subsystems.

A contrastive subdomain can be more easily recognized if it corresponds to a category that has independent existence in the grammar. In Romance languages, desinential vowels occur in a closed class of suffixes, do not alternate with stem vowels, and constitute distinct morphologically important grammatical categories. Dyck (1995) argues that contrastive specifications must be assigned separately to desinential vowels in Romance dialects of Spain and Italy (and see Frigeni 2003 for a similar argument in Campidanian Sardinian).

Many Romance dialects exhibit a kind of vowel harmony called metaphony, whereby a high desinential vowel triggers the raising of a preceding stressed vowel. Not all high desinential vowels

trigger raising, however; modifying an observation by Penny (1970), Dyck (1995) proposes the generalization in (26).

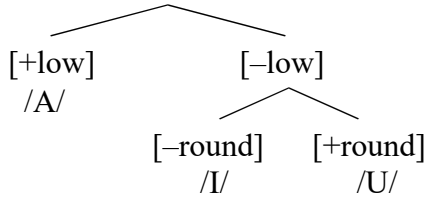
(26) Generalization about metaphony triggers (Dyck 1995)
Desinential high vowels can trigger metaphony only if they contrast with a mid-vowel in the same place.

It follows from (26) that dialects with only three desinential vowels, /I, A, U/, such as Leonese, will not have metaphony. Because the phonetics of these vowels can vary, I represent them schematically with upper case letters. Dialects with five desinential vowels /I, E, A, O, U/, such as Servigliano in Italy, can potentially have raising triggered by both /I/ and /U/. In four-vowel desinential systems of the form /I~E, A, O, U/, which have a contrast between a back high vowel /U/ and a back mid vowel /O/, but not between a high and mid front vowel, raising may be triggered by /U/ but not by /I/; examples are Central Asturian, North Central Asturian, and Montañes dialects of Santander. Conversely, raising can be triggered by /I/ but not /U/ in four-vowel systems /I, E, A, O~U/.

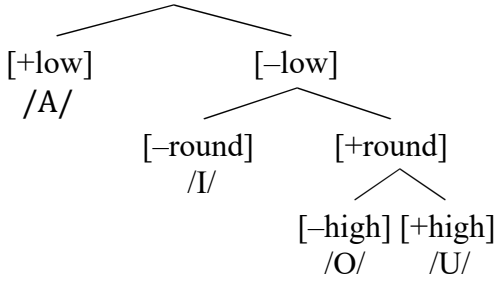
We can account for this generalization by supposing that a desinential vowel can trigger raising only if it has a contrastive [+high] feature, regardless of whether it is phonetically high. Moreover, we assume that the contrastive hierarchy of Romance vowels has the order [low] > [round] > [high]. As illustrated in (27a), a three-vowel system has room for only two contrastive features; therefore, [high] does not attain contrastive status, and we do not expect metaphony. In (27b), the contrast between /O/ and /U/ requires a third feature, [high], making /U/ contrastively [+high]. As there is no height contrast under [–round], the /I/ vowel is predicted to not cause raising.

(27) Romance desinential vowel hierarchy [low] > [round] > [high]

a. Three-vowel system



b. Four-vowel system



It is crucial to the above account that the desinential vowels be evaluated as a distinct subsystem, because in all these dialects the non-desinential vowels have contrasts between high and mid vowels in both the front and the back round vowels.

7.3 Derived contrasts: archiphonemes

In the preceding cases, contrasts in different positions are evaluated separately, and there is no relationship between the phonemes across positions. It is not the case, for example, that the desinential vowels in (27) are derived from stressed vowels. There also exist cases where certain positions give rise to a set of derived contrasts. In these cases, contrasts are initially computed with respect to a single set of underlying phonemes, but in some positions the contrastive specifications are modified.

Some types of vowel reduction lend themselves to this kind of analysis, as argued, from different perspectives, by Anderson (1996) and Spahr (2014) for Bulgarian. In stressed position, Bulgarian has the six vowels shown in (28a). Depending on the dialect, these vowels neutralize in three pairs in unstressed positions. Scatton (1984) observes that these neutralizations occur in a hierarchy: all dialects and registers neutralize unstressed /a/ and /â/, realizing them as [ə] (28b); in informal registers some dialects also neutralize /u/ and /o/ to [ʊ] (28c); and some 'non-literary varieties' further neutralize /i/ and /e/ to [ɪ] (28d).

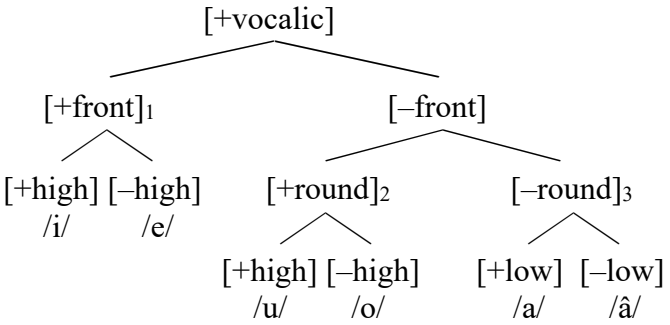
(28) Bulgarian vowels (Scatton 1984; Barnes 2006)

a. Stressed vowels			b. First reduction		c. Second reduction		d. Third reduction	
i		u	i	u	i			
						ʊ	ɪ	ʊ
e	â	o	e	o	e			
			ə		ə		ə	
	a							

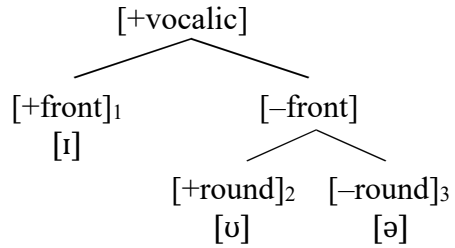
Spahr (2014) proposes that the vowel reduction patterns point to a contrastive hierarchy such as in (29a). The various reductions can now be represented as the suspension of a contrast at the bottom of the feature tree. The first reduction neutralizes the [±low] contrast under [–round] (the node numbered 3); the underspecified feature combination [+vocalic, –front, –round] is interpreted phonetically as [ə]. The second reduction neutralizes the [±high] contrast under $[+round]_2$ to [ʊ], and the third reduction neutralizes the [±high] contrast under $[+front]_1$ to [ɪ]. The completely reduced set of vowels are distinguished only by [front] and [round], with no height features (29b). Spahr points out that this analysis instantiates the Prague School notion of 'archiphoneme' (Trubetzkoy 1939; Davidsen-Nielsen 1978).

(29) Bulgarian contrastive vowel feature hierarchy (Spahr 2014)

a. Stressed vowels



b. Complete reduction



8 Conclusion

Chomsky & Halle (1968: 4) characterize a goal of linguistic theory in the following terms:

> General linguistics attempts to develop a theory of natural language as such, a system of hypotheses concerning the essential properties of any human language ... The essential properties of natural language are often referred to as "linguistic universals." ... The search for essential linguistic universals is, in effect, the study of the a priori *faculté de langage* that makes language acquisition possible under the given conditions of time and access to data.

As an important part of phonological theory, the theory of distinctive features must aspire to be universal. However, features encode contrasts in segment inventories, and contrasts within a language are inherently particular to that language. This is what complicates the search for a universal feature theory that does justice to language-particular contrast.

This chapter has illustrated that the choice for phonology is not a binary one between a universal and a language-particular theory; rather, there is a continuum in which certain aspects of the theory can be more or less universal. Thus, individual features can be universal or not, and can be assigned to phonemes with more or less attention paid to contrast. Similarly, feature hierarchies can be more or less variable across languages, and languages can be more or less similar in the way they assign contrastive domains.

However much cross-linguistic variability there is, however, does not detract from the goal of linguistic theory to characterize the phonological component of the language faculty. And to do this requires finding universal principles. Therefore, the question is not whether or not there exist phonological universals involving features and contrast, but rather at what level of abstraction they may be found.

References

Anderson, Gregory & K. David Harrison (1999). *Tyvan* (Languages of the World: Materials, 257). Munich: LINCOM Europa.

Anderson, John M. (1996). The representation of vowel reduction: Non-specification and reduction in Old English and Bulgarian. *Studia Linguistica* 50. 91–105.

Anderson, John M. (2005). Old English *i*-umlaut (for the umpteenth time). *English Language and Linguistics* 9. 195–227.

Anderson, John M. & Colin J. Ewen (1987). *Principles of dependency phonology*. Cambridge: Cambridge University Press.

Anderson, John M. & Charles Jones (1974). Three theses concerning phonological representations. *Journal of Linguistics* 10. 1–26.

Archangeli, Diana (1988). Aspects of underspecification theory. *Phonology* 5. 183–207.

Barnes, Jonathan. 2006. *Strength and weakness at the interface: Positional neutralization in phonetics and phonology.* Berlin & New York: Mouton de Gruyter.

Basbøll, Hans (2022). Phonology in Glossematics in Northern and Western Europe. In B. Elan Dresher & Harry van der Hulst (eds.) *The Oxford history of phonology*. Oxford: Oxford University Press. 331–355.

Battaner Moro, Elena & Richard Ogden (2022). John R. Firth and the London School. In B. Elan Dresher & Harry van der Hulst (eds.) *The Oxford history of phonology*. Oxford: Oxford University Press. 242–259.

Bohn, Graziela Pigatto (2015). *Aquisição das vogais tônicas e pretônicas do Português Brasileiro*. PhD dissertation, University of São Paulo.

Bohn, Graziela Pigatto (2017). The acquisition of tonic and pre-tonic vowels in Brazilian Portuguese. *Journal of Portuguese Linguistics* 16(7), 1–5. DOI: https://doi.org/10.5334/jpl.184

Calabrese, Andrea (2005). *Markedness and economy in a derivational model of phonology*. Berlin: Mouton de Gruyter.

Campos-Astorkiza, Rebeka (2009). *The role and representation of minimal contrast and the phonetics-phonology interaction*. München : Lincom Europa.

Cherry, E. Colin, Morris Halle, & Roman Jakobson (1953). Toward the logical description of languages in their phonemic aspect. *Language* 29. 34–46.

Chomsky, Noam & Morris Halle (1968). *The sound pattern of English*. New York, NY: Harper & Row.

Clements, G. N. (2001). Representational economy in constraint-based phonology. In T. Alan Hall (ed.) *Distinctive feature theory*. Berlin: Mouton de Gruyter. 71–146.

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

Clements, G. N. (2009). The role of features in phonological inventories. In Eric Raimy and Charles Cairns (eds.) *Contemporary views on architecture and representations in phonological theory.* Cambridge, MA: MIT Press. 19–68.

Davidsen-Nielsen, Niels (1978). *Neutralization and the archiphoneme: Two phonological concepts and their history*. Copenhagen: Akademisk Forlag.

Dresher, B. Elan (1998). On contrast and redundancy. Presented at the annual meeting of the Canadian Linguistic Association, Ottawa. Ms., University of Toronto.

Dresher, B. Elan (2003). Contrast and asymmetries in inventories. In Anna-Maria di Sciullo (ed.) *Asymmetry in grammar, volume 2: Morphology, phonology, acquisition*. Amsterdam: John Benjamins. 239–257.

Dresher, B. Elan (2009). *The contrastive hierarchy in phonology*. Cambridge: Cambridge University Press.

Dresher, B. Elan. (2014). The arch not the stones: Universal feature theory without universal features. *Nordlyd* 4. 165–181. Special issue on Features ed. by Martin Krämer, Sandra Ronai, & Peter Svenonius. University of Tromsø — The Arctic University of Norway.

Dresher, B. Elan (2015). The motivation for contrastive feature hierarchies in phonology. *Linguistic Variation* 15. 1–40.

Dresher, B. Elan (2016). Contrast in phonology 1867–1967: History and development. *Annual Review of Linguistics* 2. 53–73.

Dresher, B. Elan & Keren Rice (2015). Phonological typology with contrastive hierarchies. Presented at the MOLT Phonology Atelier, University of Toronto, March 2015.

Dresher, B. Elan, Daniel Currie Hall, & Sara Mackenzie (2021). The status of phoneme inventories: The role of contrastive feature hierarchies. Presented at the 12th International Conference of Nordic and General Linguistics, Workshop 1: Establishing phoneme inventories: argumentation and cross-linguistic comparability. Virtual conference hosted by the University of Oslo, June 2021.

Dresher, B. Elan, Christopher Harvey, & Will Oxford (2018). Contrastive feature hierarchies as a new lens on typology. In Larry Hyman & Frans Plank (eds.), *Phonological typology*. Berlin: de Gruyter Mouton. 273–311.

Dresher, B. Elan, Glyne Piggott, & Keren Rice (1994). Contrast in phonology: Overview. *Toronto Working Papers in Linguistics* 13. iii–xvii.

Duanmu, San (2016). *A theory of phonological features.* Oxford: Oxford University Press.

Dyck, Carrie (1995). *Constraining the phonology-phonetics interface, with exemplification from Spanish and Italian dialects.* PhD dissertation, University of Toronto.

Flemming, Edward S. (2002). *Auditory representations in phonology*. New York, NY: Routledge.

Frigeni, Chiara (2003). Metaphony in Campidanian Sardinian: A domain-based analysis. *Toronto Working Papers in Linguistics (Special Issue on Contrast in Phonology)* 20. 63–91.

Hall, Daniel Currie (2007). *The role and representation of contrast in phonological theory*. PhD dissertation, University of Toronto.

Hall, Daniel Currie (2011). Phonological contrast and its phonetic enhancement: Dispersedness without dispersion. *Phonology* 28. 1–54.

Halle, Morris (1959). *The sound pattern of Russian: A linguistic and acoustical investigation.* The Hague: Mouton. Second printing, 1971.

Hirayama, Manami (2003). Contrast in Japanese vowels. *Toronto Working Papers in Linguistics* 20. 115–132.

Hulst, Harry van der (2020). *Principles of Radical CV Phonology: A theory of segmental and syllabic structure.* Edinburgh: Edinburgh University Press.

Jakobson, Roman ([1931] 1962). Phonemic notes on Standard Slovak. In *Selected writings I. Phonological studies*, 221–230. The Hague: Mouton. [Published in Czech in *Slovenská miscellanea (Studies presented to Albert Pražak*). Bratislava, 1931.]

Jakobson, Roman. 1941. *Kindersprache, Aphasie, und allgemeine Lautgesetze*. Uppsala: Uppsala Universitets Arsskrift.

Jakobson, Roman, C. Gunnar M. Fant, & Morris Halle (1952). *Preliminaries to speech analysis*. MIT Acoustics Laboratory, Technical Report, No. 13. Reissued by MIT Press, Cambridge, Mass., Eleventh Printing, 1976.

Jakobson, Roman & Morris Halle (1956). *Fundamentals of language.* The Hague: Mouton.

Jakobson, Roman & John Lotz (1949). Notes on the French phonemic pattern. *Word* 5. 151–158.

Kean, Mary-Louise (1980). *The theory of markedness in generative grammar.* PhD dissertation, MIT, Cambridge, MA, 1975. Reproduced by the Indiana University Linguistics Club, Bloomington, IN.

Keyser, Samuel Jay & Kenneth N. Stevens (2001). Enhancement revisited. In Michael J. Kenstowicz (ed.) *Ken Hale: A life in language*. Cambridge, MA: MIT Press. 271–291.

Keyser, Samuel Jay & Kenneth N. Stevens (2006). Enhancement and overlap in the speech chain. *Language* 82. 33–63.

Lahiri, Aditi & Henning Reetz (2002). Underspecified recognition. In Carlos Gussenhoven and Natasha Warner (eds.) *Laboratory Phonology 7*. Berlin, New York: De Gruyter Mouton. 637–676. https://doi.org/10.1515/9783110197105.2.637

Liljencrants, Johan & Björn Lindblom (1972). Numerical simulation of vowel quality systems: The role of perceptual contrast. *Language* 48. 839–862.

Lindblom, Björn (1986). Phonetic universals in vowel systems. In John J. Ohala & Jeri J. Jaeger (eds.) *Experimental phonology*. New York: Academic Press. 13–44.

Mackenzie, Sara. 2013. Laryngeal co-occurrence restrictions in Aymara: Contrastive representations and constraint interaction. *Phonology* 30. 297–345.

Martinet, André (1956). *La Description phonologique avec application au parler franco-provençal d'Hauteville (Savoie)*. Geneva: Librairie Droz.

Martinet, André (1964). *Elements of general linguistics*, translated by Elisabeth Palmer. Chicago: University of Chicago Press.

Menn, Lise & Marilyn Vihman (2011). Features in child phonology: Inherent, emergent, or artefacts of analysis? In G. N. Clements & Rachid Ridouane (eds.), *Where do phonological features come from? Cognitive, physical and developmental bases of distinctive speech categories.* Amsterdam: John Benjamins. 261–301.

Mielke, Jeff (2008). *The emergence of distinctive features*. Oxford: Oxford University Press.

Moran, Steven & Daniel McCloy (eds.) (2019). PHOIBLE 2.0. Jena: Max Planck Institute for the Science of Human History. (Available online at http://phoible.org, Accessed on 2023-09-02.)

Nevins, Andrew. 2010. *Locality in vowel harmony*. Cambridge, MA: MIT Press.

Padgett, Jaye. (2003a). Contrast and post-velar fronting in Russian. *Natural Language and Linguistic Theory* 21. 39–87.

Padgett, Jaye (2003b). The emergence of contrastive palatalization in Russian. In D. Eric Holt (ed.) *Optimality Theory and language change*. Dordrecht: Kluwer. 307–335.

Penny, Ralph (1970). Mass-nouns and metaphony in the dialects of North-Western Spain. *Archivum Linguisticum* 1. 21–30.

Rice, Keren (2003). Featural markedness in phonology: Variation. In Lisa Cheng & Rint Sybesma (eds.) *The second Glot International state-of-the-article book: The latest in linguistics*. Berlin: Mouton de Gruyter. 387–427.

Rice, Keren (2007). Markedness in phonology. In Paul de Lacy (ed.) *The Cambridge handbook of phonology*. Cambridge: Cambridge University Press. 79–97.

Rose, Sharon & Rachel Walker (2011). Harmony systems. In John A. Goldsmith, Jason Riggle, & Alan C. L. Yu (eds.) *The handbook of phonological theory,* second edition, 240–290. Malden, MA & Oxford: Wiley-Blackwell.

Samuels, Bridget D. (2011). *Phonological architecture : A biolinguistic perspective*. Oxford: Oxford University Press.

Sanders, Nathan (2003). *Opacity and sound change in the Polish lexicon*. PhD dissertation, University of California, Santa Cruz.

Scatton, Ernest A. (1984). *A reference grammar of modern Bulgarian*. Columbus, OH: Slavica Publishers, Inc.

Spahr, Christopher (2014). A contrastive hierarchical account of positional neutralization. *The Linguistic Review* 31. 551–585.

Staun, Jørgen (2022). Dependency Phonology. In B. Elan Dresher & Harry van der Hulst (eds.) *The Oxford history of phonology*. Oxford: Oxford University Press. 485–508.

Stevens, Kenneth N. & Samuel Jay Keyser (1989). Primary features and their enhancement in consonants. *Language* 65. 81–106.

Stevens, Kenneth N., Samuel Jay Keyser, & Haruko Kawasaki (1986). Toward a phonetic and phonological theory of redundant features. In Joseph S. Perkell & Dennis H. Klatt (eds.) *Symposium on invariance and variability of speech processes*. Hillsdale, NJ: Lawrence Erlbaum. 432–469.

Trubetzkoy, Nikolai S. (1939). *Grundzüge der Phonologie (Travaux du Cercle Linguistique de Prague 7)*. Göttingen: Vandenhoek & Ruprecht. 6th edn, 1977.

Trubetzkoy, Nikolai S. (1969). *Principles of phonology*. Translated by Christiane A. M. Baltaxe, Berkeley & Los Angeles: University of California Press.

Twaddell, W. Freeman. 1935. *On defining the phoneme*. Language Monograph 16. Baltimore: Waverly Press.

Veer, Marijn van ’t, Bert Botma, Florian Breit, & Marc van Oostendorp (2023). The structure and content of phonological primitives. In Florian Breit, Bert Botma, Marijn van 't Veer, & Marc van Oostendorp (eds.) *Primitives of Phonological Structure*. Oxford: Oxford University Press. 1–36.

Zhang, Xi (1996). *Vowel systems of the Manchu-Tungus languages of China.* PhD dissertation, University of Toronto.