The Motivation for Contrastive Feature Hierarchies in Phonology

B. Elan Dresher

University of Toronto

1. Introduction

The notion that phonological features are organized into contrastive hierarchies has been entertained at different times in the history of linguistics. Contrastive feature hierarchies, in the form of 'branching trees', first became prominent in phonological theory in the work of Roman Jakobson and Morris Halle and their colleagues (Jakobson, Fant & Halle 1952; Cherry, Halle & Jakobson 1953; Jakobson & Halle 1956). A branching tree of this kind appears in Halle's *The sound pattern of Russian* (*SPR,* 1959), but no such tree can be found in Chomsky and Halle's *The sound pattern of English* (*SPE,* 1968) nine years later. For the next forty years, contrastive hierarchies played at best a minor role in phonological theory, until they reappeared in publications emanating from the University of Toronto and independently in the work of G. N. Clements, where they were incorporated into an 'accessibility scale' (Clements 2001) and later into a 'robustness scale' (Clements 2009).

I will consider contrastive feature hierarchies in the context of developments in phonological theory, with special attention to the work of Jakobson, Halle, and Clements, who have been particularly influential. My main focus will be on the motivation for such hierarchies: what principles govern the ordering of the features? I will show that they have been motivated by three different principles, set out in (1).

(1) The main principle that determines the ordering of features in a hierarchy is

a. *Activity*: to identify the contrastive features that are relevant to the phonological computation.

b. *Minimality*: to minimize redundancy in phonological representations and to maximize the amount of information conveyed by each feature.
c. *Universality*: to express universal tendencies in the nature of phonological inventories and the order of acquisition of feature contrasts.

These principles do not necessarily conflict in every case, but in practice situations arise where they lead in different directions. To some extent Jakobson and Halle (Jakobson & Halle 1956; Halle 1959) and Clements (2001; 2003a; b; 2009) appeal to all these principles, though they do so with differing emphases: Jakobson began by appealing to Activity, Halle came to stress Minimality, and Clements focused on Universality. I will argue on behalf of the centrality of Activity, which I understand to be the original and most compelling motivation for feature hierarchies.

Section 2 introduces the notion of a contrastive feature hierarchy by considering the branching tree for Russian in Halle 1959 and its predecessors in Jakobson & Lotz 1949 and Jakobson, Fant & Halle 1952. Section 3 explores the roots of contrastive hierarchies in the writings of the Prague School. I argue that their original motivation was to account for phonological activity, what I call the Activity Principle (1a).

In section 4, I show that in the course of the 1950s Jakobson and Halle came to gradually adopt a different rationale for feature hierarchies, namely the Minimality Principle (1b), which places a premium on minimizing the number of specifications required to characterize a phonological inventory. Section 5 describes how the shift away from Activity and toward Minimality had major consequences for the debate about the nature of the phoneme, and thereby played a crucial role in the development of phonological theory. Halle's (1959) argument that branching trees are required to ensure that all the phonemes in an inventory are properly distinct is presented in section 6. I propose that Halle's Distinctness Condition is part of a larger and still

relevant argument against using pairwise comparisons or notions of minimal contrast as a way of arriving at contrastive representations.

Section 7 reviews the disappearance of branching feature trees from generative phonology until the late 1980s, when they began to reappear in the literature and became the focus of the theory of Modified Contrastive Specification at the University of Toronto. In this approach the Activity Principle is again central in determining what the contrastive feature hierarchy is in a given inventory. A strong version of this principle, called the Contrastivist Hypothesis, holds that only contrastive features may be active in the phonology. Another consequence of adopting Activity as the overriding principle in establishing contrastive representations is the subordination of Minimality and Universality when these conflict with Activity: thus, feature hierarchies may be uneconomical and show cross-linguistic variation.

Section 8 looks at the independent revival of the contrastive hierarchy in the work of Clements in the 2000s. I argue that though Clements sometimes appealed to Activity in motivating his proposed hierarchies, in crucial respects he gave priority to Universality and to Minimality in the form of cross-linguistic generalizations about feature economy. In section 9, I review Clements's appeal to loanword adaptation, a form of activity, to support his feature hierarchy for the consonants of Hawaiian, and show, following Herd (2005), that the same arguments motivate a slightly different hierarchy for the closely related New Zealand Māori.

In section 10, I consider some further consequences of making Activity the preeminent rationale for feature hierarchies, and explore some issues in the connection between contrast and activity, notably the status of the Contrastivist Hypothesis. Section 11 is a brief conclusion.

2. Halle 1959 (*SPR*): The 'branching tree'

On p. 46 in *SPR* is Figure I–1, a magnificent diagram that shows the contrastive feature specifications of every phoneme ('morphoneme') of Russian. The caption beneath the diagram reads:

> Branching diagram representing the morphonemes of Russian. The numbers with which each node is labeled refer to the different features, as follows: 1. vocalic vs. nonvocalic; 2. consonantal vs. nonconsonantal; 3. diffuse vs. nondiffuse; 4. compact vs. noncompact; 5. low tonality vs. high tonality; 6. strident vs. mellow; 7. nasal vs. nonnasal; 8. continuant vs. interrupted; 9. voiced vs. voiceless; 10. sharped vs. plain; 11. accented vs. unaccented. Left branches represent minus values, and right branches, plus values for the particular feature.

[Put example (2) about here]

In a branching diagram like this, the *ordering* of the features is crucial: different orders can result in different specifications. Thus, feature 6, [strident], applies within the labials to distinguish the [+strident] fricatives *f, f,, v, v,,* from the [−strident] stops *p, p,, b, b,, m, m,*;[1] but it does not apply to the characteristically strident sounds *č, š, ž* (IPA *ʧ, ʃ, ʒ*) because these already form a separate group, due to divisions made higher in the tree. Similarly, feature 8, [continuant], does not apply to the labials, because the labial fricatives have already been distinguished from the labial stops by [strident]. Feature 9, [voiced], does not apply to vowels, *j,* liquids, nasals, *c* (IPA *ts*), *č,* and *x*.

In each of these cases, a different feature ordering could have resulted in a different outcome. Thus, *č, š,* and *ž* are *potentially* [+strident]; the labial stop-fricative distinction could potentially be characterized by [continuant]; and every phoneme could be assigned a contrastive

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[1] Halle (1959) designates palatalized consonants (IPA *Cʲ*) as *C,*.

value of [voiced] if that feature were high enough in the order: of the phonemes not assigned a value of [voiced] in (2), the vowels, *j*, liquids, and nasals are all phonetically voiced, hence potentially contrastively [+voiced], and *c, č,* and *x* are all phonetically voiceless, hence potentially [–voiced]. It is therefore important to have principles that guide the ordering of the features. What these principles are in *SPR* will be discussed in §4.

The branching feature tree has antecedents in the work of Roman Jakobson and his collaborators. It appears overtly in Jakobson, Fant & Halle 1952. They propose that listeners identify phonemes by distinguishing them from every other phoneme in the system. These distinctions are effected by making a series of binary choices that correspond to the oppositions active in the language. By 'oppositions active in the language' they mean that not all phonetic properties of a phoneme are equally important to the phonology. It is thus *phonological activity* that determines what the features are, and how they are ordered in the tree (1a). Feature activity can be defined as in (3), which adapts a formulation by Clements (2001).[2]

(3) Feature activity (based on 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.

Going back a bit further, a branching tree can be shown to underlie the feature specifications in an article on Standard French by Jakobson and Lotz (1949). I say 'underlie'

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[2] Clements (2001) states also that a feature is said to be active if it is required for the expression of lexical contrasts. Though there is a sense in which a contrastive feature can be said to be active merely by virtue of being included in the phonological representation, I would like to construe 'activity' more narrowly, as in (3); see §10 for further discussion.

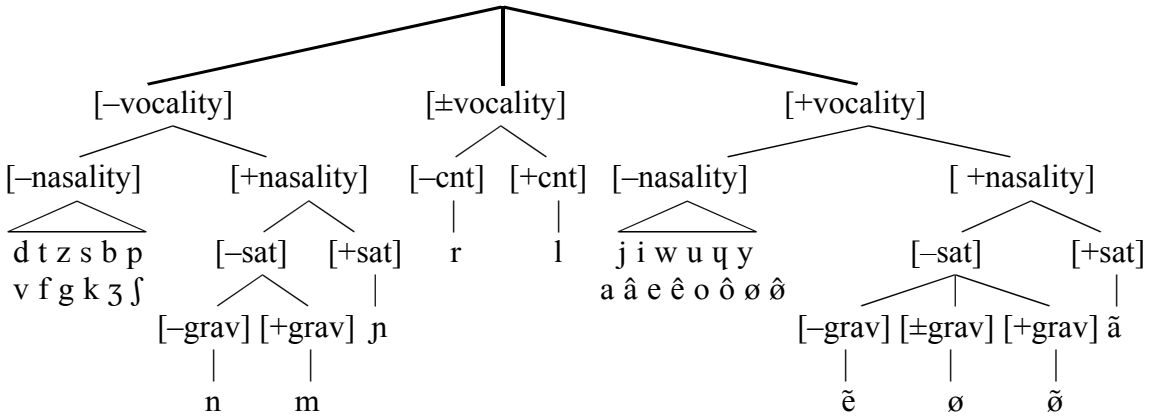
because the tree itself does not appear. However, their representations are consistent with such a tree, and are difficult to explain otherwise. Jakobson and Lotz's analysis presupposes the feature ordering in (4).[3] Each feature applies in turn to each branch of the inventory in which it is contrastive, as shown in (5).

(4) Feature hierarchy for Standard French (Jakobson and Lotz 1949)

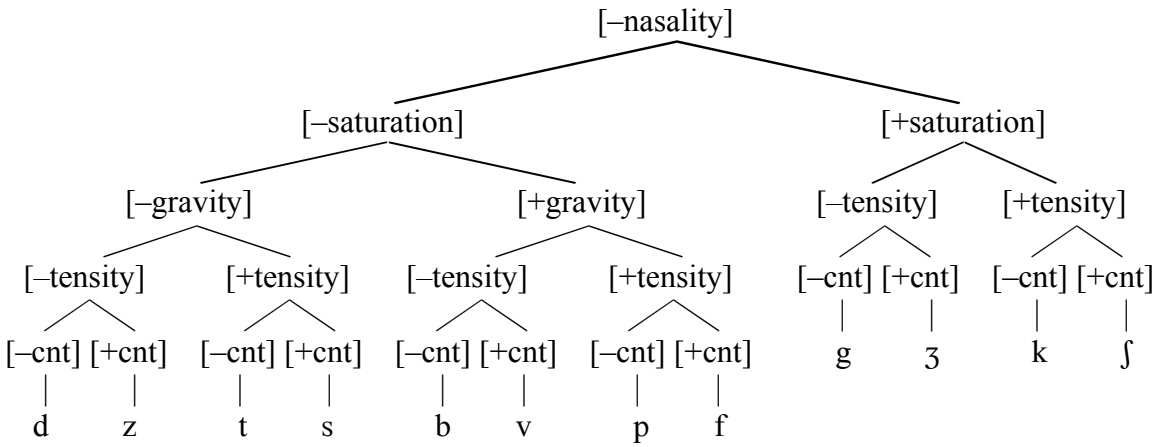
[vocality] > [nasality] > [saturation] > [gravity] > [tensity] > [continuousness]

(5) Feature tree for Standard French (Jakobson and Lotz 1949)

a. Top of the hierarchy: [vocality] > [nasality]

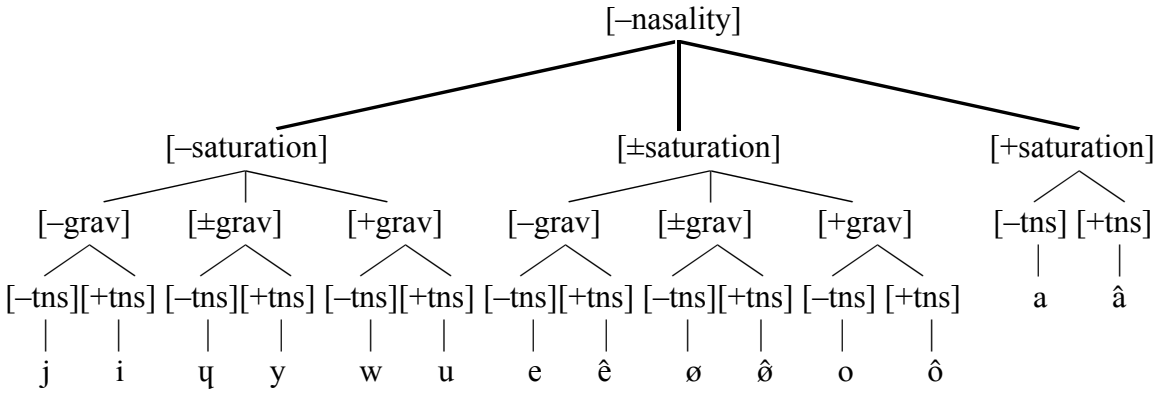


b. Non-nasal consonants [−vocality, −nasality]



[3] The notation [F1] > [F2] indicates that [F1] is ordered before [F2].

c. Non-nasal vowels and glides [+vocality, −nasality]



The first decision pertains to [vocality] (5a): phonemes are either [−vocality] (consonants), [+vocality] (vowels and glides), or a third intermediate value, [±vocality], for liquids. The second feature to apply is [nasality]. It is contrastive in the consonants and vowels, but not among the liquids. If a feature is not contrastive in a branch of the tree, it is not assigned to that branch. For example, there are only two liquids, /r, l/, and only the last feature, [continuousness], distinguishes them. The nasal consonants and vowels are each further distinguished from each other by [saturation] and [gravity].

Let us turn now to the non-nasal consonants, under [−vocality, −nasality] in (5b). The next choice is [saturation]: these phonemes are either unsaturated (labials and front coronals) or saturated (postalveolars and velars). If we choose [−saturation], the next feature is [gravity]: coronals are [−gravity] and labials are [+gravity]. The final choices are [tensity] (which in this group functions like [voiceless]) and [continuousness] in each branch. In the [+saturation] branch, there are no contrasts with respect to [gravity], so the next features that apply are [tensity] and then [continuousness].

In the non-nasal vowels and glides in (5c), [saturation] makes a three-way division between the high vowels and glides ([−saturation]), the low vowels ([+saturation]), and the mid vowels, which have an intermediate value ([±saturation]). The remaining contrastive features are

[gravity] and [tensity]; [continuousness] is not contrastive among the vowels and glides. The feature [gravity] makes a ternary division in the vowels and glides in (5a) and (5c): front unrounded vowels and glides are [–gravity], back rounded are [+gravity], and front rounded are [±gravity]. The feature [tensity] in (5c) distinguishes high vowels from glides, and tense from lax non-high vowels.

In keeping with the Activity Principle (1a), Jakobson & Lotz (1949) give empirical arguments to support their choice of feature specifications for Standard French, based on two types of phonological activity: the adaptation of foreign sounds, and language-internal alternations. To support their use of the feature [saturated], they observe (1949: 153):

> the difference between velar and palatal is irrelevant in French phonemics…These contextual variations do not hinder French speakers from rendering the English velar *ŋ* through the French palatal *ɲ*... or the German 'ich-Laut' through *ʃ*. The advanced articulation of *k g* before *j* or *i*, as well as the existence of *ŋ* instead of *ɲ* before *w*…illustrates the unity of the saturated consonants in French.

It is quite clear, then, that the Activity Principle is the dominant motivation supporting the feature hierarchies in Jakobson & Lotz 1949 as well as in Jakobson, Fant & Halle 1952. This connection between contrastive features and phonological activity is a natural development of ideas that go back considerably earlier in Prague School phonology, and I explore these in the next section.

3. Prague School phonology: The role of contrastive properties

An idea that can be traced to the beginnings of modern phonology is that only some properties of a segment are *relevant* to the phonology, and these are the distinctive, or contrastive, properties (Trubetzkoy 1969 [1939]). Relevance in this sense can be equated with activity: a feature is

relevant to the phonology of a language if it plays a role in characterizing its phonological patterns. An early expression of this idea can be found in Jakobson's (1962 [1931]) discussion of the difference between the Czech and Slovak vowel systems. Jakobson cites the observation of B. Hála that the simple vowels of Slovak "correspond completely both in their production and in the auditive impression they produce to the vowels of Standard Czech"…except for a short front vowel *ä* that occurs in dialects of Central Slovak. Jakobson notes (1962 [1931]: 224) that the presence of *ä* in Slovak, though "a mere detail from a phonetic point of view…determines the phonemic make-up of all the short vowels." The 'phonemic make-up' of a vowel phoneme can be equated with its contrastive properties. Jakobson diagrams the Czech and Slovak short vowel systems as in (6).[4]

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

a. Standard Czech

Front/unround	Back/round
i	u
e	o
a	

b. Standard Slovak

Front	Back
i	u
e	o
ä	a

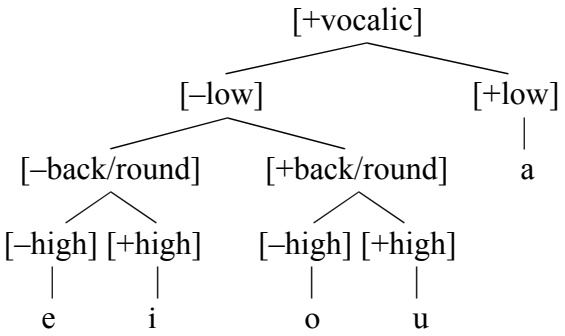
The Slovak front-back contrast in the low vowels sets up a parallel contrast in the non-low vowels. In Czech, the low vowel has no contrastive tonality feature. In the non-low vowels, Jakobson suggests that the two dimensions of front/back and round/unround (in his terms, acuteness/gravity and flatness/non-flatness) form an 'indissoluble synthesis'.[5] Jakobson's

[4] I have inverted and reflected Jakobson's diagrams to the more familiar modern orientation of high vowels at the top and front vowels to the left.

[5] Compare the proposal of Kaye, Lowenstamm & Vergnaud (1985) that in such languages the BACK and ROUND lines are 'fused'.

analysis of Czech implies an ordering [low] > [back/round], [high], as shown in (7).[6] This ordering *explains* why /a/ has no tonality features. In (7) I assume for concreteness the ordering [low] > [back/round] > [high], though the ordering [low] > [high] > [back/round] fits this data equally well.

(7) Feature hierarchy for Standard Czech vowels (based on Jakobson 1962 [1931])



Trubetzkoy (1969 [1939]) reviews a number of five-vowel systems. He observes that many such systems are like Czech in that the low vowel does not participate in tonality contrasts. He cites Latin as another example of this kind of system. However, he observes that other types of vowel systems exist. In Archi (East Caucasian, formerly Artshi), 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*. This means that all vowels are divided into rounded and unrounded vowels, while the back or front position of the tongue proves irrelevant…" (Trubetzkoy 1969 [1939]: 100–101). This analysis, displayed informally in (8a), corresponds to ordering [round] first, followed by [high] and [low].

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[6] Features separated by a comma in an ordered list of features are not crucially ordered with respect to each other. Thus, [F1] > [F2], [F3] indicates that [F2] and [F3] are ordered after [F1], but are not crucially ordered with respect to each other; that is, either [F1] > [F2] > [F3] or [F1] > [F3] > [F2] will produce the same result.

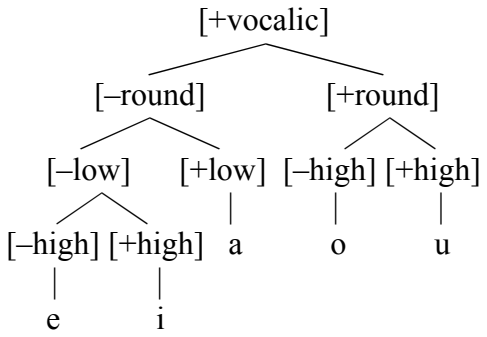
Since [round] goes first, [low] is contrastive only in the unrounded vowels. The data underdetermines the relative ordering of [low] and [high]; (8b) has [low] > [high] .

(8) Archi vowel contrasts (Trubetzkoy 1969 [1939])

a. Archi vowel inventory

Unround	Round
i	u
e	o
a	

b. Archi contrastive hierarchy



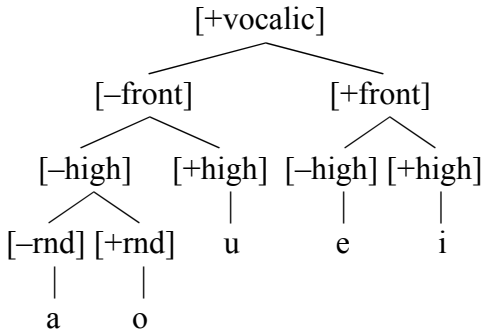
Trubetzkoy argues that neutralization of the opposition between palatalized and non-palatalized consonants before *i* and *e* in Japanese shows that these vowels are put into opposition with the other vowels /a, o, u/. The governing opposition is that between front and back vowels, lip rounding being irrelevant (9a). This analysis corresponds to ordering [front] first. The tree in (9b) is based on the underlying values proposed by Hirayama (2003); contrary to Trubetzkoy, she argues that [round] (which she calls [peripheral]) is relevant in the Japanese vowel system, but only to distinguish between /o/ and /a/.

(9) Japanese vowel contrasts (Trubetzkoy 1969 [1939])

a. Japanese vowel inventory

Front	Back
i	u
e	o
	a

b. Japanese contrastive hierarchy



Thus we can understand Trubetzkoy's remark in his 1936 article addressed to psychologists and philosophers, that the correct classification of an opposition "depends on one's point of view"; but "it is neither subjective nor arbitrary, for the point of view is implied by the system" (Trubetzkoy 2001 [1936]: 20). Feature ordering is a way to incorporate 'point of view' into the procedure of determining contrastive properties. Different orders result in different contrastive features, and hence in different ways of classifying a given contrast. The correct ordering is 'implied by the system', meaning, suggested by the pattern of phonological activity in the system.

To take one final example, consider Trubetzkoy's (1969 [1939]) remarks about German and Czech *h*. According to Trubetzkoy, German /h/ stands apart from all other phonemes by virtue of being the only laryngeal phoneme. We can instantiate this idea by ordering the laryngeal feature over other features that could apply to /h/, as illustrated in (10).

(10) German consonants (Trubetzkoy 1969 [1939])

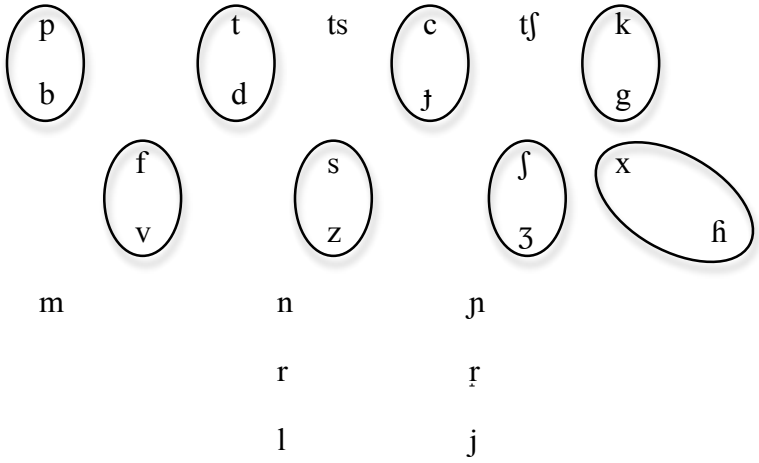
p	pf	t	ts			k	
b		d				g	
	f		s	ʃ		x	h
	v		z				
m		n				ŋ	
			l		r		

Looking at the Czech consonant inventory (11), one might suppose that Czech *ɦ* is similarly isolated, for it, too, is the only laryngeal consonant. However, Trubetzkoy (1969 [1939]: 124) proposes that Czech *ɦ* (which he writes as *h*), forms a minimal contrast with *x*. The reason is that the distinction between these phonemes can be neutralized, for they behave

phonologically like a voiced ~ voiceless pair, like the other such pairs in Czech (circled). Trubetzkoy (1969 [1939]: 124) concludes:

> The *h* in Czech thus does not belong to a special laryngeal series, which does not even exist in that language. It belongs to the guttural series, for which, from the standpoint of the Czech phonological system, only the fact that lips and tip of tongue do not participate is relevant.

(11) Czech consonants (Trubetzkoy 1969 [1939])



Thus, /ɦ/ and /x/ form a minimally contrastive pair in Czech, but to see them that way we have to *abstract away* from differences that are not deemed to be phonologically relevant. Trubetzkoy's analysis can be implemented in terms of a contrastive hierarchy: in Czech, the laryngeal feature is lower in the hierarchy than it is in German, too low to be contrastive for /ɦ/. Thus, it is the Activity Principle that is the key to determining what the relevant contrastive features are.

4. Halle 1959 again: Changing rationales for contrastive features

Despite these antecedents, this is not the approach taken by *SPR*. A change in rationale for feature hierarchies is already apparent in Jakobson & Halle 1956, when discussing Standard

French. Though their analysis is similar to that of Jakobson & Lotz 1949, their main justification is that theirs is "the unique solution" on the grounds that it is optimal in terms of the number of binary decisions that have to be made. In the 1950s, Jakobson and Halle became interested in the then new field of information theory (Shannon & Weaver 1949), and began to look at branching trees as a way of conveying information about phonemes in the most economical way (cf. Cherry, Halle & Jakobson 1953). This criterion, which I have called the Minimality Principle (1b), came to overshadow Activity as the major influence on feature ordering. According to Minimality, features in a hierarchy are ordered so as to minimize redundancy in phonological representations and to maximize the amount of information conveyed by each feature.

In *SPR* (29–30), Minimality is expressed by Condition (5), given in (12); roughly speaking, Conditions (3) and (4) require that the phonological description meet basic conditions of adequacy.[7] Halle (1959: 29) states the rationale for Minimality as follows: "Since we speak at a rapid rate…it is reasonable to assume that all languages are so designed that the number of features that must be specified in selecting individual morphemes is consistently kept at a minimum."

(12) Condition (5) in *SPR*: 29–30

In phonological representations the number of specified features is consistently reduced to a minimum compatible with satisfying Conditions (3) and (4).

Halle observes (1959: 44–45) that his analysis of Russian contains 43 phonemes specified by 271 feature specifications, or 6.3 distinctive feature statements per phoneme. He compares 6.3

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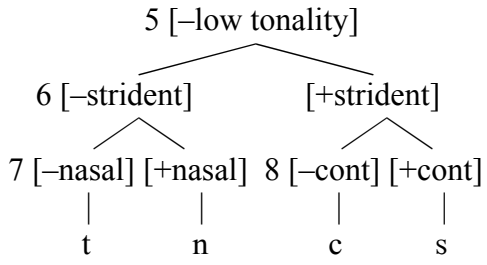
[7] Thus, there are constraints on the choice of features that may prevent Minimality from being the *only* principle guiding feature hierarchies; in the absence of such constraints, we could always select features and order them so as to achieve the absolute minimal number of specifications for any inventory (see Cherry, Halle & Jakobson 1953 for discussion).

with the lower limit of $\log_2 43 = 5.26$ specifications, which would represent the most efficiently branching tree for 43 phonemes. He goes on, "It is to be emphasized that this comparison must be treated with a great deal of caution: its only purpose is to show that the minimization process has achieved results of the type that might reasonably be expected."

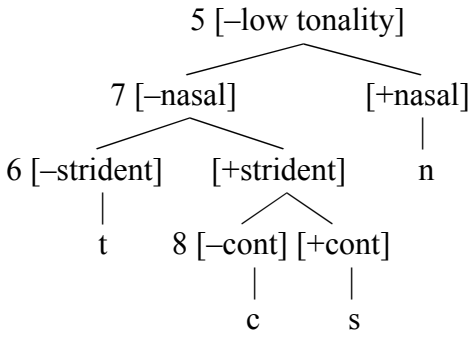
This emphasis on Minimality rather than Activity as the rationale for feature ordering has various consequences for the form of the *SPR* tree in (2). For example, consider the somewhat unintuitive ordering of [strident] (feature 6) > [nasal] (feature 7). A simplified diagram illustrating selected phonemes is shown in (13a). The tree in (13b) shows a different ordering, in which nasals are not within the scope of [strident]. However, as Halle (1959: 36) points out, this tree is less symmetrical and requires more specifications. The *SPR* tree in (13a) uses 8 specifications for 4 phonemes (not counting the topmost specification which is common to all segments in the tree), which comes to 2.00 specifications per phoneme = $\log_2 4$. This is the minimum number of specifications for 4 phonemes that can be achieved with strictly binary features. The alternate tree in (13b) uses 9 specifications, or 2.25 specifications per phoneme.

(13) Ordering of [strident] and [nasal] in Russian

a. Halle 1959: Fig. 1-1



b. An alternative ordering



Similar results hold if we repeat the exercise for the entire portion of the tree in (2) in which the features [strident] or [nasal] could potentially be relevant, that is, the part of the tree containing the consonantal phonemes from /t/ to /x,/, including the features 4 [compact], 5 [low

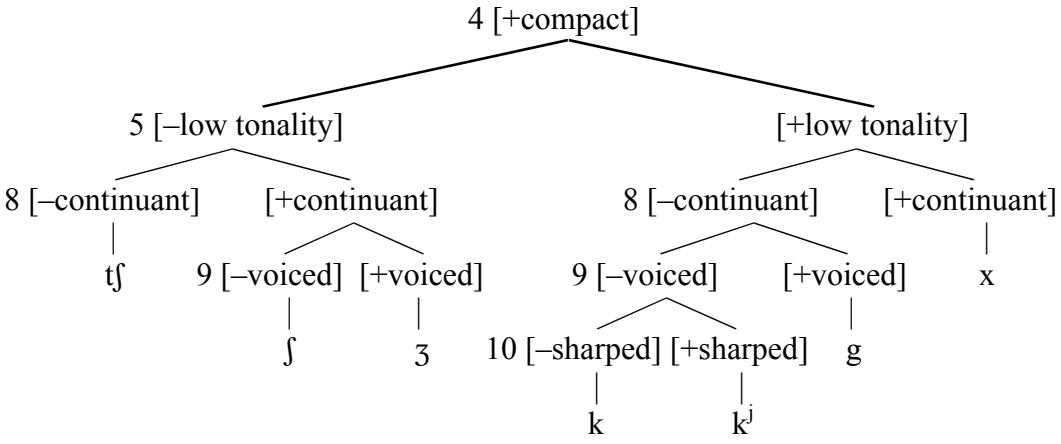
tonality], 6 [strident], 7 [nasal], 8 [continuant], 9 [voiced], and 10 [sharped]. The ordering as given in (2) requires 144 feature specifications (5.14 specifications per phoneme), whereas adjusting the ordering so that [nasal] precedes [strident] requires 149 feature specifications (average 5.32). Thus, Minimality accounts for the ordering of [strident] > [nasal], because Condition (5) prefers the *SPR* ordering over the alternative with [nasal] > [strident].

The ordering in another part of the tree had momentous consequences for the development of phonological theory, as we will see in the next section.

5. Consequences of Minimality for the development of generative phonology

Consider the fragment of the *SPR* tree shown in (14).[8] In the given ordering, /tʃ/ and /x/ are unspecified for [voiced]. But as Halle famously pointed out, these segments (as well as /ts/) behave phonologically like other voiceless obstruents with respect to voicing assimilation. In *SPR*, this fact is accounted for by the rules in (15).

(14) Subtree showing /tʃ/ and /x/ unspecified for [voiced] (*SPR*)



[8] In this section and henceforth I use IPA symbols for Russian segments: /ts, tʃ, ʃ, ʒ, kʲ/ rather than Halle's /c, č, š, ž, k,/, etc.

(15) Phonological rules affecting [voiced] in *SPR*: 63–64

a. Rule P 1b: Unless followed by an obstruent, /ts/, /tʃ/, and /x/ are voiceless.

b. Rule P 2: If an obstruent cluster is followed by a word boundary or by a phonemic phrase boundary, all segments in the cluster are voiceless.

c. Rule P 3a: If an obstruent cluster is followed […] by a sonorant, then with regard to voicing the cluster conforms to the last segment.

An example occurs in the derivation of [safxós] ‘state farm’ from /sovxóz/, shown in (16). The Ø specification for [voiced] of /x/ is immediately filled in by Rule P1b, so the fact that /x/ has no lexical specification for [voiced] has no further effect on the phonology; in particular, /x/ is specified [−voiced] at the point where Rule P 3a (regressive voicing assimilation) applies.[9]

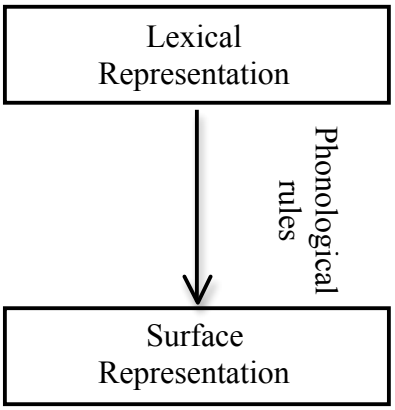
(16) Partial derivation of [safxós] ‘state farm’ (*SPR*)

Underlying		/# s o v x ó z #/
	[voiced]	+ Ø +
Rule P 1b (15a)		# s o v x ó z #
	[voiced]	+ − +
Rule P 2 (15b)		# s o v x ó s #
	[voiced]	+ − −
Rule P 3a (15c)		# s o f x ó s #
	[voiced]	− − −

[9] See Kulikov 2012 for a recent phonetic study of voicing processes in Russian. Kulikov finds that voicing assimilation and final devoicing do not result in complete neutralization of voiced and voiceless stops with respect to all phonetic cues. What the implications of these findings are for the phonological status of these processes in Russian is not clear. I will continue to assume that the processes discussed here are phonological.

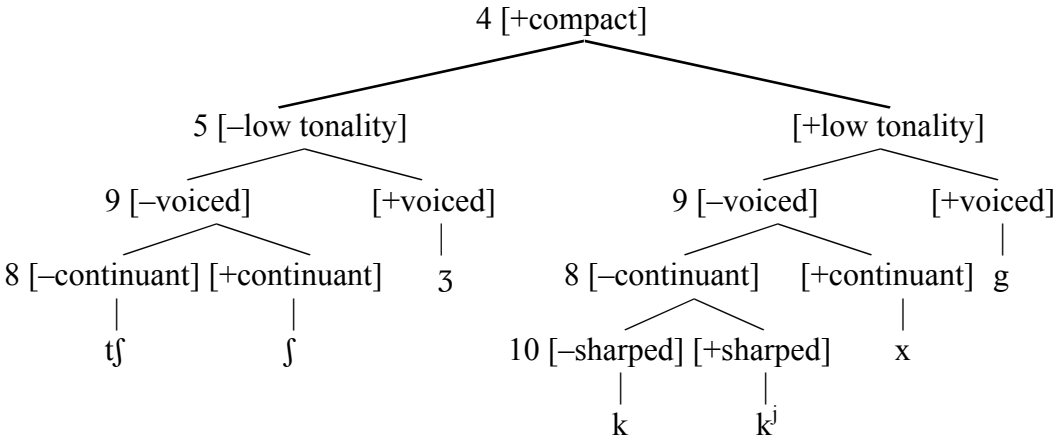
This derivation played a role in Chomsky and Halle's arguments against the neo-Bloomfieldian phonemic level (Halle 1959; Chomsky 1964; see Dresher 2005 for discussion). Chomsky and Halle wanted to recognize only two significant phonological levels: the lexical representation, more or less the older morphophonemic level; and a phonetic surface level, characterized by the universal set of phonological features (17). Between underlying and surface levels they envisioned a seamless transition effected by an ordered set of phonological rules. In this theory, there was no place for making a basic distinction between feature-filling rules like P 1b, and feature-changing rules like P 2 and P 3a. Consequently, the distinction between contrastive and non-contrastive features also became unimportant to the phonology, and the link between contrastive specification and phonological activity was lost.

(17) Two significant levels of representation (Chomsky & Halle 1968)



It is interesting to note that a minimal change in the ordering of [continuant] and [voiced] in *SPR* would have put this problem in a different light. By ordering [voiced] slightly higher, as in (18), the 'unpaired' phonemes become contrastively [−voiced], even though they have no voiced counterparts that are minimally different.

(18) Alternate ordering of [voiced] and [continuant] in Russian



In this case the contrastive hierarchy forces a tradeoff, in that now the voiced consonants /ʒ/ and /g/ are unspecified for [continuant]. Is this a good result? Dresher & Hall (2009) argue that it is. For while there is clear evidence from phonological activity that /ts, tʃ, x/ are specified [–voiced], there is no clear evidence that /ʒ/ and /g/ have contrastive specifications for [continuant]. On the contrary, it appears that the continuancy of /g/ is unstable in Russian in a number of ways.

First, the phonetic realization of /g/ varies across Russian dialects: in some southern dialects of Russian, /g/ is realized as continuant [ɣ] or [ɦ]; the latter is the cognate of Russian /g/ in Ukrainian (Medushevsky & Zyatkovska 1963; Butska 2002). All these realizations are voiced, but they vary in continuancy. There is also (morpho)phonological evidence in the alternations resulting from the First Velar Palatalization, whereby, in terms of *SPR*, consonants that are [+compact, +low tonality] become [–low tonality]. Thus, continuant /x/ becomes continuant [ʃ], and non-continuant /k/ becomes non-continuant [tʃ]; however non-continuant /g/ changes to continuant [ʒ]. Some examples are given in (19) (Dresher & Hall 2009; see Radišić 2009 for a similar analysis of such alternations in Serbian).

(19) /g/-/ʒ/ alternations in Russian (Dresher & Hall 2009)

a. Adjectives

Positive (M S)	Comparative	Gloss
tʲixij	tʲiʃe	‘quiet(er)’
ʒarkij	ʒartʃe	‘hot(ter)’
dorogoj	doroʒe	‘dear(er)’

b. Verbs

3 P	3 S	Gloss
maxut	maʃet	‘wave(s), wag(s)’
pekut	petʃet	‘bake(s)’
strigut	striʒet	‘shear(s)’

c. Denominal adjectives

Noun	Adjective	Gloss
tʃerepaxa	tʃerepaʃij	‘turtle’ / ‘testudian’
volk	voltʃij	‘wolf’ / ‘lupine’
vrag̊	vraʒij	‘enemy’ / ‘hostile’

If the Activity Principle had remained a dominant consideration in *SPR*, the facts of Russian would have suggested that the feature [voiced], not [continuant], is contrastive over all the obstruents.[10] This result would have pointed to (18) as displaying the correct feature ordering,

[10] Just to be clear, I am not arguing that the above facts conclusively prove that /k, g, x/ lack contrastive values for [continuant]; however, faced with a choice between assigning them either [voiced] or [continuant], the facts are more consistent with them having contrastive values for [voiced] and lacking contrastive values for [continuant] than the opposite.

rather than the tree in *SPR*. But phonological theory was moving in a direction in which the link between contrastive specification and activity was no longer operative.

6. Branching trees and distinctness

One might wonder why the branching tree is retained at all in *SPR*. In addition to the information-theoretic considerations discussed above, Halle (1959) argues that phonological features must be ordered into a hierarchy because this is the only way to ensure that segments are kept properly distinct. Thus, he proposes (1959: 32) that phonemes must meet the Distinctness Condition (20).

(20) The Distinctness Condition (Halle 1959)

Segment-type {A} will be said to be different from segment type {B}, if and only if at least one feature which is phonemic in both, has a different value in {A} than in {B}; i.e., plus in the former and minus in the latter, or vice versa.

(21) The Distinctness Condition: Example

a. Full specification for features 1 and 2

	A	B	C
Feature 1	−	+	+
Feature 2	–	−	+

b. Underspecified feature values that violate the Distinctness Condition

	A	B	C
Feature 1	−	+	0
Feature 2	0	−	+

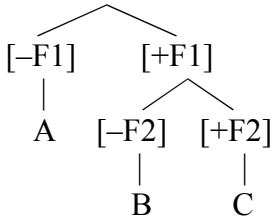
In the example in (21), we assume three phonemes A, B, and C, which have the specifications in (21a) for the features 1 and 2 ([F1] and [F2], respectively). Not all these feature

specifications are contrastive; (21b) is an underspecified version of (21a), a candidate for a set of underlying contrastive representations. In (21b), A is 'different from' B, because A is [–F1] whereas B is [+F1]. By the same token, B is 'different from' C due to [F2]. However, A is not 'different from' C; that is, since [F2] and [F1] are not specified in A and C, respectively, it is impossible to tell from (21b) whether A and C are the same or different.[11]

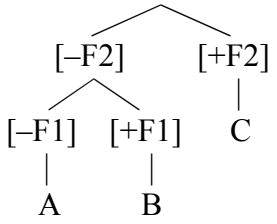
The specifications in (21b) violate the Distinctness Condition because no feature hierarchy yields this result, as shown in (22). Ordering [F1] > [F2] yields an additional specification on C, while ordering [F2] > [F1] yields an additional specification on A. The feature matrices resulting from these trees are shown in (23). In these representations, every segment is distinct from every other one in terms of the Distinctness Condition: B is different from A and from C as before; but now A and C are also properly distinct, because of [F1] in (23a), and because of [F2] in (23b). Ordering features into a hierarchy guarantees this result.

(22) Possible feature hierarchies for (21)

a. [F1] > [F2]



b. [F2] > [F1]



[11] It may be easier to recognize the lack of proper contrast in (21b) if we remove B from the inventory; nobody would propose (i) as a way of contrasting two segments with binary features:

i. Underspecified feature values that violate the Distinctness Condition

	A	C
Feature 1	−	0
Feature 2	0	+

(23) Feature matrices corresponding to the trees in (22)

a. [F1] > [F2]

	A	B	C
[F1]	−	+	+
[F2]		−	+

b. [F2] > [F1]

	A	B	C
[F1]	−	+	
[F2]	–	−	+

Though Halle (1959) does not mention any other method for computing underspecified contrastive representations, the Distinctness Condition serves as an argument against arriving at contrastive specifications by means of pairwise comparisons. For example, the algorithm in (24), proposed by Archangeli (1988), designates as contrastive only features in pairs of phonemes that differ by only a single feature.[12]

(24) Pairwise Algorithm (Archangeli 1988)

a. Fully specify all segments.

b. Isolate all pairs of segments.

c. Determine which segment pairs differ by a single feature specification.

d. Designate such feature specifications as ‘contrastive’ on the members of that pair.

e. Once all pairs have been examined and appropriate feature specifications have been marked ‘contrastive’, delete all unmarked feature specifications on each segment.

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[12] It should be noted that Archangeli (1988) showed that the algorithm in (24) *fails* to yield satisfactory specifications in certain inventories, part of her argument against the theory of Contrastive Specification proposed by Steriade (1987). Dresher (2009: 11–30) argues that while the algorithm is indeed faulty, its shortcomings do not affect theories of contrastive (under)specification based on feature hierarchies.

The algorithm in (24) designates as contrastive only features that are involved in 'minimal contrasts', that is, in segment pairs that differ by only a *single* feature (24c). Another way of arriving at the same result is the definition of contrast in Nevins 2010, given in (25).

(25) Minimal contrast (Nevins 2010: 98)

A segment S with specification [aF] is contrastive for F if there is another segment S_0 in the inventory that is featurally identical to S, except that it is [−aF].

Pairwise comparisons yielding minimal contrasts are a popular method of contrastive specification (Padgett 2003, Calabrese 2005, Nevins 2010 explicitly, and many others implicitly).[13] Let us consider what results this method would give starting from the fully specified feature specifications of the inventory in (21a). If we make pairwise comparisons of the phonemes in (21a), we find that Feature 1 is the only feature that distinguishes A from B, and Feature 2 is the only feature that distinguishes B from C. Feature 2 on A is not required to distinguish A from any other segment, and is in fact predictable, from Feature 1, since A is the only segment that is [−F1]. By the same token Feature 1 on C is predictable from Feature 2, since C is the only segment that is [+F2]. Thus, this method yields precisely the specifications in (21b) that the Distinctness Condition rules out as improperly contrastive. Dresher (2009: 11–30) argues that Halle (1959) is correct in stating that only a hierarchical approach can guarantee that all segments in an inventory are properly contrasted; in addition to cases like (21b) that may look to be proper contrastive representations but in fact are not, there are inventories for which pairwise comparisons and minimal contrast do not yield *any* sensible results.

This, then, is another rationale for feature hierarchies. However, it is neutral with respect to the criteria, as in (1), that govern the ordering of features. For purposes of contrast, it is

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[13] Dresher (2009: 13–14) traces this approach at least as far back as Martinet (1960).

enough to have *some* feature hierarchy to ensure proper contrast; additional principles are required to determine what the ordering should be in any given language.

How contrastive features are defined will turn out to have important implications for the issue of whether phonology computes only contrastive features, a matter I take up in sections 8 and 10.

7. The fall and revival of branching trees in generative phonology

The declining importance of contrastive specification in generative phonology can already be seen in *SPR*, which nevertheless retains a role for it and the contrastive feature hierarchy. The coup de grâce was delivered by Stanley (1967), who challenged the 'branching diagrams' as well as the whole notion of underspecification. But Stanley remarked: "There is obviously some kind of hierarchical relationship among the features which must somehow be captured in the theory."

The contrastive hierarchy disappeared from generative phonology for a generation. With some exceptions, the branching tree did not return even with the revival of interest in theories of underspecification in the 1980s.[14] One notable exception is Cairns 1988. Cairns makes explicit use of a contrastive hierarchy, which he calls a 'coding tree' (26), to arrive at underlying specifications, as part of his Markedness Theory of Syllable Structure (MTSS). The MTSS is noteworthy in that it is one of the few theories proposed in the 1980s that makes use of a contrastive hierarchy, in conjunction with underspecification and markedness. The feature

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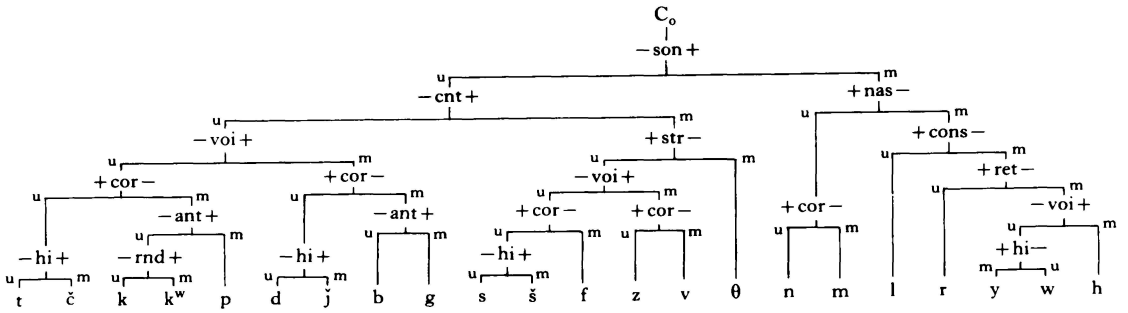
[14] Notable among these were the theories of Radical Underspecification (Archangeli 1984 and Pulleyblank 1986, building on proposals by Kiparsky 1982 and 1985) and Contrastive Specification (Steriade 1987; Clements 1987; Christdas 1988). These theories also employed the criteria of Activity, Minimality, and Universality in varying proportions; see Dresher 2009: 117-130 for discussion.

hierarchy that gives rise to (26) is [sonorant] > [nasal] > [consonantal] > [continuant] > [strident], [retroflex] > [voiced] > [coronal] > [high], [anterior] > [round].[15]

(26) Master inventory of English onset segments (Cairns 1988: 217)



The feature hierarchy also makes an appearance in Boersma 1998; a feature tree for Dutch short vowels is given in (27). Boersma writes (1998: 402), "It may well be that this tree tells us more about the psychological realities of Dutch vowels than any feature matrix. There are seven underspecifications, most of which are reflected in regional or positional variations".[16]

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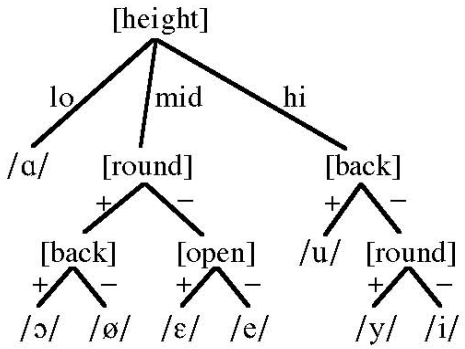
[15] The full feature ordering cannot be reconstructed from the tree in (26). I assume [nasal] > [continuant], otherwise the latter feature would have applied in the [+sonorant] branch. For the same reason I assume [consonantal] > [continuant]. The relative ordering of [retroflex] relative to [continuant] and [strident] is underdetermined: I have put it below [continuant] parallel to [strident], but other orderings are consistent with (26). Whether one of [high] and [anterior] is ordered ahead of the other depends on the exact definitions of these features.

[16] Note that the tree in (27) has [round] > [back] in the mid vowels, but [back] > [round] in the high vowels. Having different orderings in different branches of the feature tree is a logical possibility (noted also by Halle 1959: 35–36), but I have been assuming that this does not occur. The seven underspecifications are: /ɑ/ for [round] and [back]; /u/ for [round]; /ɛ, e/ for [back]; and /ɔ, o/ for [open] (assuming that [open] applies only in mid vowels in this feature system).

(27) Feature hierarchy for Dutch short vowels (Boersma 1998: 402)



Starting in the early 1990s, phonologists at the University of Toronto began to develop a theory of contrastive underspecification that came to be called Modified Contrastive Specification (MCS, Dresher, Piggott & Rice 1994; Dresher & Rice 2007). Over time this approach incorporated some of the Prague School concepts discussed in section 3, including Activity (1a) as a central principle.[17]

A hypothesis that flows naturally from the Activity Principle is what Hall (2007: 20) calls the *Contrastivist Hypothesis* (28a), which states that *only* contrastive features can be active in phonological processes. From this hypothesis it follows as a corollary (28b) that active features must be contrastive.

(28) The Contrastivist Hypothesis and its corollary

a. The Contrastivist Hypothesis (Hall 2007)

The phonological component of a language L operates only on those features which are necessary to distinguish the phonemes of L from one another.

[17] See Dresher 2009: 163f. for references and a detailed review of early work in the MCS framework. For more recent applications and developments, see Hall 2011, Mackenzie 2011, 2013, Ko 2012, Spahr 2014, and Oxford 2015.

b. Corollary to the Contrastivist Hypothesis

If a feature is phonologically active, then it must be contrastive.

Second, contrastive features are determined by ordering features into a contrastive hierarchy. I call this method, the 'branching trees' of the literature, the *Successive Division Algorithm* (Dresher 1998, 2003, 2009).[18]

(29) The Successive Division Algorithm

Assign contrastive features by successively dividing the inventory until every phoneme has been distinguished.

Third, we learn from the examples in §3 that the contrastive hierarchy must allow for *variation* (30) if we are to consistently adhere to the Activity Principle and the Contrastivist Hypothesis.

(30) Variability of Feature Ordering

The contrastive feature hierarchy is not universal but may vary (within limits to be determined).

8. Clements (2001, 2003a, b, 2009): Feature hierarchies and phonological inventories

In a series of publications, G. N. Clements proposed a central role for contrastive feature hierarchies. In fact, Clements (2001) comes close to adopting the Contrastivist Hypothesis. He proposes (2001: 71–2) that "phonological representations should be freed of superfluous representational elements, leaving only those that are essential to an understanding of lexical, phonological, and phonetic generalizations." He argues "for a general principle of representational economy according to which features are specified in a given language only to

[18] See Dresher 2009: 16–17 for a more procedurally explicit version of this algorithm.

the extent that they are needed in order to express generalizations about the phonological system."

He proposes a principle of *Active Feature Specification*, given in (31). According to Clements (2001: 77), "The term 'active feature' is used to designate a feature or feature value that is required for the expression of lexical contrasts or phonological regularities in a language, including both static phonotactic patterns and patterns of alternation. In this view, whether or not a given feature or feature value is specified in a given language can only be determined from an examination of its system of contrasts and sound patterns."

(31) Active Feature Specification (Clements 2001: 77)

All and only those features that are active in a given language occur in its lexical and phonological representations.

This formulation is consistent with what I have called the Activity Principle, and comes close to the Contrastivist Hypothesis. But Clements adopts a weaker version of the Contrastivist Hypothesis. He proposes conditions for feature specification for each level of phonological representation (32).

(32) Conditions for feature specification (Clements 2001: 77–8)

a. Lexical level: distinctiveness

A feature or feature value is present in the lexicon if and only if it is distinctive.

b. Phonological levels: feature activity

A feature or feature value is present at a given phonological level if it is required for the statement of phonological patterns (phonotactic patterns, alternations) at that level.

c. Phonetic level: pronounceability

Feature values are present in the phonetics if required to account for relevant aspects of phonetic realization.

A feature is *distinctive* in a given segment if it is required to distinguish that segment from another. Thus (32a) is consistent with the Contrastivist Hypothesis. The difference comes at (32b), where Clements allows for the possibility of adding non-contrastive features if they are required to account for phonological activity; that is, it is possible that some active features may not be contrastive.

Clements (2001: 79) does in fact entertain the possibility of constraining (32b) as required by the Contrastivist Hypothesis: "An interesting question is whether one can maintain the…strong hypothesis" stated in (33), which would hold that "only lexically distinctive values are phonologically active." He continues, "This hypothesis is attractive in that, if true, it would place strong constraints on the nature of feature representation."

(33) Clements's version of the Contrastivist Hypothesis (Clements 2001: 79 (7))

Lexical feature representations are identical to phonological feature representations.

Clements concludes, however, that the Contrastivist Hypothesis cannot be maintained "in its strong form", because there exist phonologically active features that are absent from lexical specifications; that is, non-contrastive features may be active in the phonology. Thus, Clements (2001) argues on empirical grounds that the Contrastivist Hypothesis is too strong. This could be the case. However, we have to be clear as to what constitutes a test of the adequacy of the Contrastivist Hypothesis. I have argued above that the feature hierarchy must be variable, in order to account for the different patterns of phonological activity in similar-looking inventories (e.g. 5-vowel systems, German /h/ vs. Czech /ɦ/, etc.). Therefore, the Contrastivist Hypothesis

fails if there is *no possible ordering* of features available in which only contrastive features are active. But this is not the criterion that Clements uses. To see this, it is necessary to consider his approach to the feature hierarchy, which he calls the Accessibility Hierarchy (2001), and later the Robustness Hierarchy (2009).

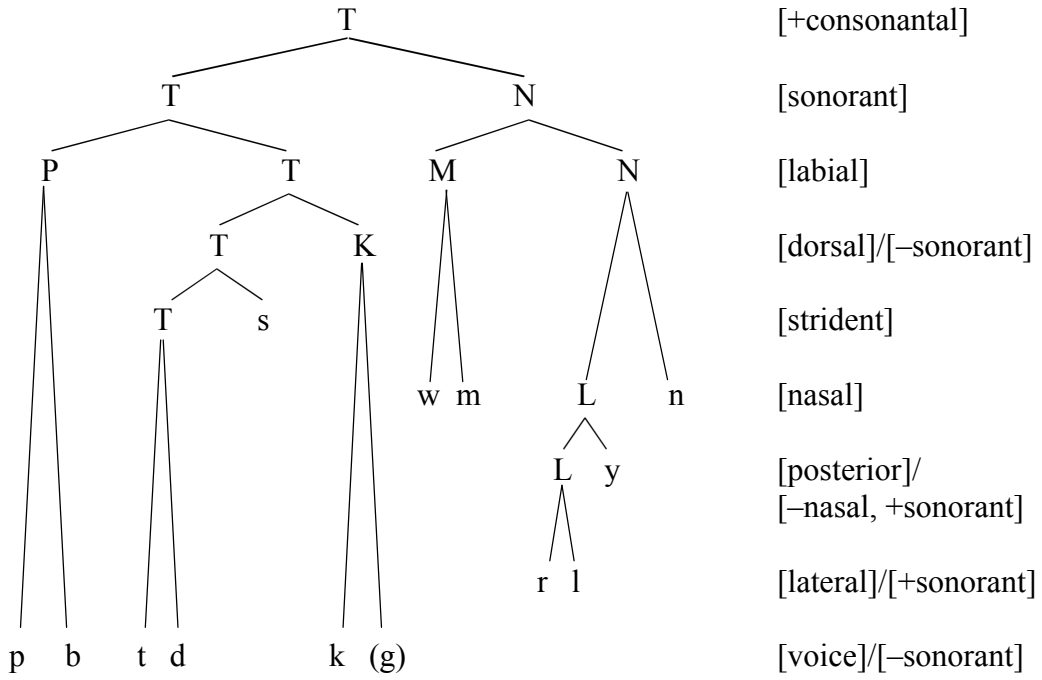
Clements (2001: 79) writes that "features can be ranked according to a universal hierarchy of accessibility. At the top of the hierarchy are features that are highly favored in the construction of phoneme systems, while at the bottom are features that are highly disfavored." He proposes the Accessibility Hierarchy in (34). This scale works *almost* like the contrastive hierarchy introduced earlier, but not exactly. An important difference is that the ranking does not strictly dictate whether a feature will actually be specified. For example, [coronal] is at the top of the hierarchy, but Clements asserts that it is usually left unspecified.

(34) Partial ranked scale of feature accessibility for consonants

	Feature:	*In:*		*Feature:*	*In:*
a.	[coronal]		f.	[nasal]	
b.	[sonorant]		g.	[posterior]	[+sonorant, -nasal]
c.	[labial]		h.	[lateral]	[+sonorant]
d.	[dorsal]	[-sonorant)	i.	[voice]	[-sonorant]
e.	[strident]				

Consider the sample 'typical' inventory, shown in (35). Upper-case letters represent underspecified (archiphonemic) segments. For example, T represents all [+consonantal] segments in the top row, [+consonantal, –sonorant] in the second row, [+consonantal, –sonorant, –labial] in the third row, and so on.

(35) Consonant accessibility (Clements 2001: 84, Fig. 1)



The feature [coronal] is considered the default place, and it functions as a default, remaining unspecified. This is in contrast to the earlier understanding of branching trees, as governing contrastive feature specification. In the conventional interpretation, if [coronal] is at the top of the order, then the whole inventory would be in its contrastive scope.

But this is not the most important difference between Clements's approach and the one I argued for earlier. The main difference is the emphasis that Clements puts on a *universal* feature hierarchy. Actually, his approach is quite nuanced (Clements 2001: 84–5):

> While it is possible that the hierarchy is simply given as such in universal grammar, it is not unreasonable to suppose that it can be recovered, at least in large part, from the speaker's linguistic experience through massive exposure to data allowing a calculation of relative phoneme frequencies and other phenomena related to feature accessibility. If this is true, it is possible that universally-given feature rankings might be contradicted in certain languages, giving rise to

> language-particular rerankings. However, such reversals should be relatively limited, given that the constraints on production and perception that underlie the notion of accessibility are presumably the same, or very similar, for all normal speakers. We expect, then, that the ranking in [(35)] or one similar to it should be largely respected from one language to another.

Thus, Clements does allow for some variability in the hierarchy, and he sometimes makes adjustments for particular languages. The key question is how much relative weight should be given to the phonological patterning exhibited by a particular language, on the one hand, as compared to universal tendencies with respect to phonological inventories, on the other. In general, Clements favours the latter, what I have called the Universality Principle (1c): the main principle that determines the ordering of features in a hierarchy is to express universal tendencies in the nature of phonological inventories and the order of acquisition of feature contrasts.[19]

One reason that Clements prefers to maintain a universal feature order is because of his interest in feature economy, a form of minimality. According to Clements (2009: 27), "*Feature Economy* is the tendency to maximize feature combinations (see Clements 2003a, b, after sources in de Groot 1931, Martinet 1955, 1968)." That is, it is better to use fewer features by getting the most out of each feature. As Clements notes, this is not an absolute restriction on inventories, but rather a tendency.

Clements (2009: 34) observes that cross-linguistically inventories reflect the effects of feature economy working together with the accessibility scale, renamed now the robustness scale

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[19] The notion that there are universal tendencies in the acquisition and ordering of certain contrasts or features goes back to Jakobson 1941. The Universality Principle continued to play a role in Jakobson & Halle 1956, though they allowed for a certain amount of variation in the ordering of features.

(36). The robustness scale is a somewhat revised version of the accessibility scale. Rather than a strict ranking, features are placed in five groups of decreasing likelihood of occurring. There are also some changes in the ordering. Among other changes, [continuant] and [posterior] have been promoted, and [strident] and [lateral] have been demoted.

(36) Robustness scale: Consonants (Clements 2009)

Feature:	*Feature*
a. [±sonorant]	c. [±voiced]
[labial]	[±nasal]
[coronal]	d. [glottal]
[dorsal]	e. others
b. [±continuant]	
[±posterior]	

In order to compute feature economy in a given inventory, one must know which feature contrasts are operative in the system. To allow for the computation of the economy of a large number of inventories, Clements (2009) is inclined to interpret the contrasts in inventories in accordance with the robustness hierarchy, favouring it over other possible analyses. To illustrate his approach, he again considers a typical consonant inventory, shown in (37); capital letters indicate consonant types.

(37) Typical consonant inventory (Clements 2009)

P	T		K
	S		
M	N		
W	L ~ R	J	H ~ ʔ

In any such inventory with a contrast between /T/ and /S/, Clements deems them to be distinguished by [continuant], not [strident], because the former is higher on the robustness scale. Similarly, the /L/ ~ /J/ contrast could be based on [continuant] or [posterior], but not [lateral]. These may be the correct analyses in many inventories. The crucial cases arise when phonological patterning diverges from the proposed universal ordering.

To sum up, Clements (2001: 77) appeals to Activity (1a): "whether or not a given feature or feature value is specified in a given language can only be determined from an examination of its system of contrasts and sound patterns." But he gives preference to Universality (1c) and Minimality (1b), in the form of feature economy, to the extent possible.

9. Loanword adaptation and the Activity Principle

Recall that Jakobson & Lotz (1949) gave empirical arguments for their choice of features for Standard French, based in part on the adaptation of foreign words. In exactly the same spirit, Clements (2001: 86) supports his assignment of feature specifications to the consonants of Hawaiian (38).

(38) Hawaiian consonants

p		k	ʔ
m	n		h
w	l		

Clements proposes that Hawaiian consonants have the feature ordering in (39). This hierarchy follows the 2001 Accessibility Hierarchy in (34). The feature [coronal], though at the top of the list, is skipped for reasons discussed above. After [sonorant] (39a) and [labial] (39b) apply, [dorsal] and [strident] are skipped for lack of any contrastive work to do. Then comes [nasal] (39c). Concerning the choice of the next two features, Clements (2001: 86) writes, "It

remains to distinguish /l h ʔ/, which are so far specified only as [+sonorant]. The features [posterior], [lateral], and [voice] are useless for this purpose, as they are all lexically redundant in Hawaiian. We therefore pass on to the lower-ranked features [spread glottis] and [constricted glottis], not included in [(34)], whose specifications accomplish this purpose."[20]

(39) Hawaiian feature hierarchy (Clements 2001)

a. First, [sonorant] distinguishes /m, n, w, l, ʔ, h/ from /p, k/.

b. Next, [labial] splits off /p, m, w/ from the rest, leaving /p/ and /k/ isolated.

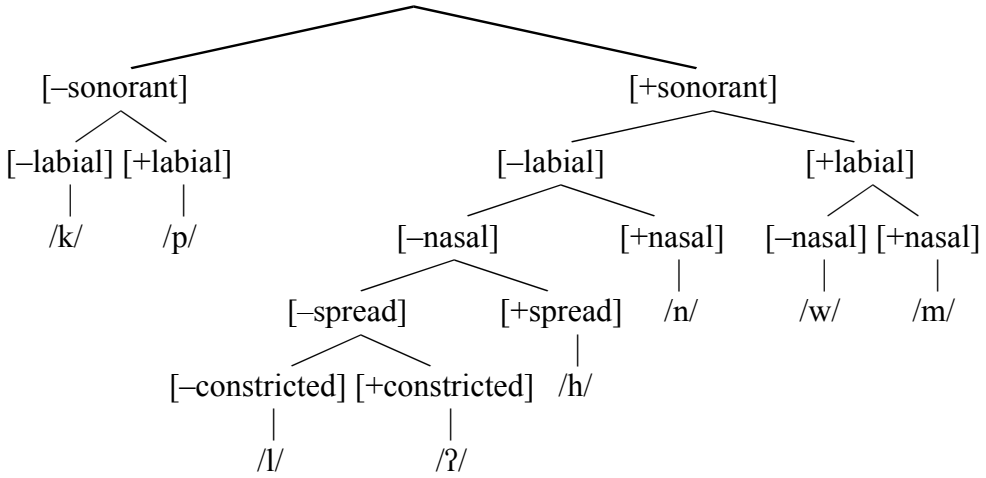
c. Next, [nasal] makes /m, n/ unique, and isolates /w/.

d. Then, [spread glottis] applies uniquely to /h/.

e. Then [constricted glottis] divides /ʔ/ from /l/.

This ordering leaves /k/ as the default for any non-native consonant that is specified [–sonorant, –labial]. I present this ordering as a tree in (40).

(40) Hawaiian feature hierarchy as a branching tree



[20] The feature [lateral] could actually serve to distinguish /l/ from /h/ and /ʔ/, but this feature is not consistent with the adaptation of English /r/ as /l/ in (41c); compare also *rose* > *loke* (Clements 2001: 86), and *truck* > /kalaka/, *carrot* > /kaaloke/, etc. (Herd 2005: 99–100). This may be an example of Clements tacitly appealing to Activity to override his basic hierarchy.

Clements argues that productive adaptation patterns of English loanwords into Hawaiian support this analysis. For example, [b] and [f] are borrowed as /p/: they are [−sonorant], and they are [+labial], hence /p/. Coronal obstruents and [g] all become /k/: they are [−sonorant, −labial], hence they become /k/. In (41) are examples of the adaptation of English coronal fricatives.[21]

(41) Adaptation of English coronal fricatives as /k/ in Hawaiian

a.	[s] → /k/	lettuce → /lekuke/	soap → /kope/
b.	[z] → /k/	dozen → /kaakini/	
c.	[ʃ] → /k/	brush → /palaki/	machine → /mikini/

Herd (2005) builds on Clements's analysis, and looks at patterns of loanword adaptation in related Polynesian languages. In New Zealand (NZ) Māori, with a slightly larger consonant inventory (42), coronal obstruents are adapted as /h/, not as /k/ or /t/ (43).

(42) New Zealand Māori consonants

p	t	k
f		h
m	n	ŋ
w	r	

(43) Adaptation of English coronal fricatives as /h/ in New Zealand Māori (Herd 2005)

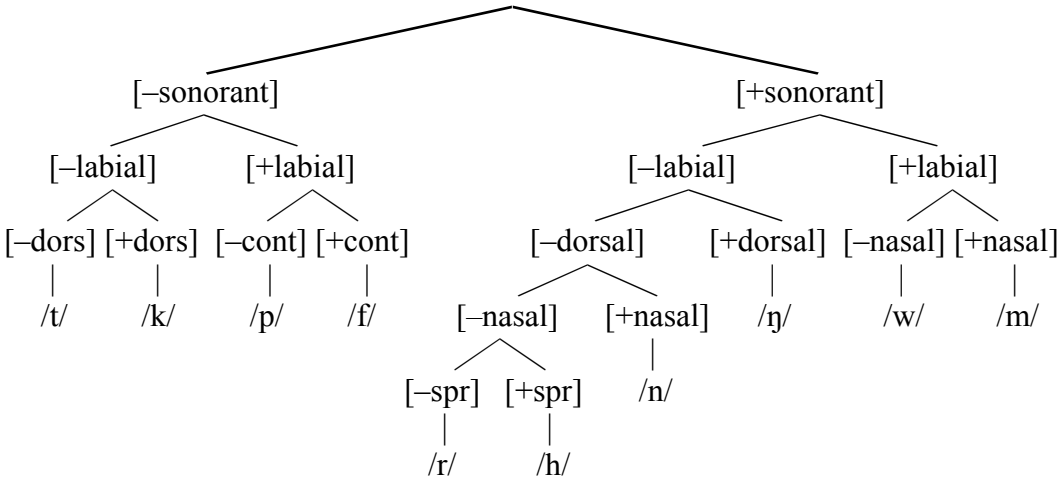
a.	[s] → /h/	glass → /karaahe/	sardine → /haarini/
b.	[z] → /h/	weasel → /wiihara/	rose → /roohi/
c.	[ʃ] → /h/	brush → /paraihe/	sheep → /hipi/

[21] Notice also the expected adaptation of /t/ (41a) and /d/ (41b) as /k/: /t, d/ are [−sonorant, −labial] = Hawaiian /k/. The realization of English /r/ in (41c) as Hawaiian /l/ is also expected: /r/ is [+sonorant, −labial, −nasal, −spread glottis, −constricted glottis] = Hawaiian /l/.

This pattern of adaptation is surprising from the perspective of the above analysis of Hawaiian. Before looking into this result further, we need to augment the Hawaiian feature hierarchy, which does not make enough distinctions to completely differentiate the larger NZ Māori inventory. Three pairs of NZ Māori phonemes remain undifferentiated if we simply apply the Hawaiian feature hierarchy as it is in (39) and (40): /t, k/ are both [–sonorant, –labial], /p, f/ are both [–sonorant, +labial], and /n, ŋ/ are both [+sonorant, –labial, +nasal].

Continuing to follow the Accessibility Hierarchy in (34), we can distinguish /t/ from /k/ and /n/ from /ŋ/ by adding [dorsal] in between [labial] and [nasal]. Making /k/ contrastively [+dorsal] effectively removes it as a possible adaptation for English coronals. We can distinguish /p/ from /f/ by adding [continuant] somewhere near the bottom of the hierarchy. Finally, [constricted glottis] can be removed because it has no contrastive function in the absence of /ʔ/. The result is the hierarchy [sonorant] > [labial] > [dorsal] > [nasal] > [spread glottis] > [continuant], shown in (44).

(44) Feature hierarchy for NZ Māori based on (34)



We can see that if we follow the hierarchy in (44) for NZ Māori, we incorrectly end up with /t/ = [–sonorant, –labial, –dorsal] as the default consonant that ought to be used for English coronal obstruents, rather than /h/. The first problem that strikes us with (44) is that /h/ is on the

[+sonorant] side of the tree, making it ineligible to serve as the adaptation of non-native [–sonorant] consonants. No amount of tinkering with the feature ordering further down can compensate for this mismatch.

Phonologists have differed as to whether /h/ and /ʔ/ should be characterized as sonorants or obstruents. In a recent review of the issue, Botma (2011) observes, "While these are like sonorants with respect to their vocal tract shape, their laryngeal setting is antagonistic to voicing"; the latter is problematic, as many consider spontaneous voicing to be a defining characteristic of sonorants. Apart from the phonetic problems, Botma also finds that analyzing /h/ and /ʔ/ as sonorants is, in many languages, "dubious on phonological grounds." Whether glottal consonants pattern as sonorants or obstruents appears to vary cross-linguistically; Parker (2011) observes that though "/h/ and /ʔ/ pattern phonologically with prototypical sonorants in some languages", these languages tend to be in the minority.[22]

Taking Activity in the form of loanword adaptation as our guide, the evidence suggests that /h/ in NZ Māori patterns with the obstruents as [–sonorant], and this is what Herd (2005) proposes. Given the similarity between Hawaiian and NZ Māori, we might expect that the former, too, should classify the glottal consonants as [–sonorant].[23] Herd (2005: 97–101) shows that the Hawaiian adaptation patterns cited by Clements (2001) can be accounted for equally

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[22] Parker (2011) reports that in the P-base sample of 549 languages in Mielke 2008, "there are 65 distinct phonological processes in which /h/ and/or /ʔ/ pattern solely with consonants that are unambiguously obstruents. In 21 other cases they group with sonorants".

[23] Herd's (2005: 69) survey of the reflexes of Proto-Polynesian consonants in seven Polynesian languages shows that, with the exception of PP */ŋ/ (and */k/) appearing as Tahitian /ʔ/, all instances of /h/ and /ʔ/ in the modern languages derive from obstruents, providing additional evidence that they pattern with the obstruents in Polynesian.

successfully if the glottals are transferred to the [–sonorant] branch of the tree in (40). The phoneme /k/, now contrastively specified [–sonorant, –labial, –spread glottis, –constricted glottis] remains the default adaptation for foreign non-labial and non-glottal obstruents.

Reclassifying /h/ as [–sonorant] in NZ Māori is necessary, but does not suffice, to account for the adaptation pattern in (43). For if we leave the feature hierarchy as it is in (44), except with /h/ now in the [–sonorant] branch, /t/ will still emerge as the default adaptation for English coronal fricatives: /t/ is now contrastively specified [–sonorant, –labial, –dorsal, –spread glottis], and /h/ is the same except it is [+spread glottis].[24]

Herd (2005) proposes that the contrastive status of /h/ is different in these languages. Hawaiian has both /h/ and /ʔ/. Following Avery & Idsardi (2001), Herd suggests that the existence of this contrast activates a laryngeal dimension they call *Glottal Width*. Glottal Width has two values, [constricted glottis] for /ʔ/, and [spread glottis] for /h/. This is as in Clements's (2001) analysis. But NZ Māori has no /ʔ/, so there is no contrast within Glottal Width. Therefore, Herd proposes that [spread glottis] is not accessible in this system, and that the feature hierarchy for NZ Māori is as in (45), displayed as a tree in (46).

(45) NZ Māori feature hierarchy (Herd 2005)

a. First, [sonorant] distinguishes /m, n, ŋ, w, r/ from /p, t, k, f, h/.

b. Next, [labial] splits off /p, f/ and /m, w/ from the rest.

c. Next, [dorsal] makes /k/ and /ŋ/ unique.

d. Next, [nasal] makes the remaining sonorants unique.

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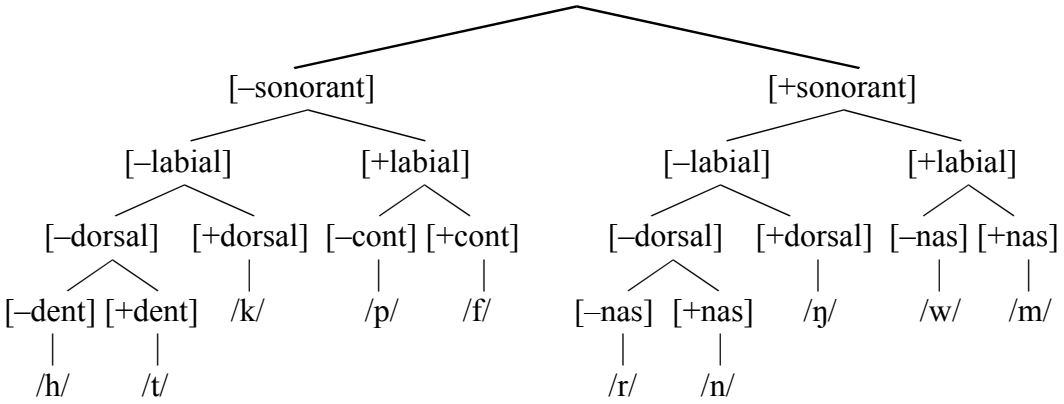
[24] If one were to argue that English coronal fricatives are perceived as [+spread glottis] and hence borrowed as /h/ in NZ Māori, one would have to explain why the same is not the case in Hawaiian, which also has /h/.

e. Then, [dental] applies to /t/, leaving /h/ as none of the above.

f. Finally, [continuant] distinguishes between the labials /p/ and /f/.

(46) NZ Māori feature hierarchy in (45) as a branching tree



As in Hawaiian, [sonorant] and [labial] are at the top of the hierarchy. Because of the /t/ ~ /k/ contrast and an additional dorsal, /ŋ/, the feature [dorsal] is contrastive here, unlike in Hawaiian. Addition of this feature limits /k/ to being the adaptation for English velars, as shown in (47a). Next comes [nasal], as in Hawaiian. But now [spread glottis] does not come so high in the order. Rather, the next feature to be assigned is [dental] for /t/, chosen because English interdental fricatives are adapted as /t/ (47b, c).[25] This leaves /h/ as the default consonant that ought to be used for other English coronal obstruents.

(47) Other adaptations of English consonants in New Zealand Māori (Herd 2005: 103)

a. [g] → /k/ fig → /fiki/ guitar → /kitā/

b. [θ] → /t/ oath → /oati/ thread → /tarete/

c. [ð] → /t/ weather → /weta/

I conclude that the same logic that leads Clements (2001) to posit one feature hierarchy for Hawaiian leads us to a slightly different hierarchy for NZ Māori. There may be universal

[25] The adaptations in (47b, c) suggest that NZ Māori /t/ and /h/ are distinguished by [dental] rather than by [continuant]; otherwise, we would expect English /θ, ð/ to be adapted as /h/.

tendencies governing the ordering of features, but these must be established empirically, by a consistent adherence to the Activity Principle.

10. Further consequences of variable feature hierarchies and the Activity Principle

The above example shows that if we put the Activity Principle first, even two related languages like Hawaiian and NZ Māori can have contrastive feature hierarchies that differ in certain crucial aspects. If we give priority to Universality, by contrast, we would assume that their feature hierarchies were more similar than indicated in the above analyses. And if our priority were to maximize Minimality, we observe that Clements's (2001) analysis of Hawaiian uses five features to distinguish eight phonemes, which is not very economical. The same is true of Herd's (2005) analysis of NZ Māori, which uses six features for ten phonemes; though [sonorant] and [labial] at the top of the hierarchy result in symmetrical, hence optimally economical, splits, greater economy is achievable if we were to use the same features under [labial] in both sides of the tree in (46). In this case, simply moving [continuant] up the hierarchy would make both [nasal] and [dental] redundant, because [continuant] by itself could distinguish between /h/ ~ /t/, /r/ ~ /n/, and /w/ ~ /m/, in addition to /p/ ~ /f/. But this more economical analysis would not account for the patterns of loan adaptation.[26]

The Activity Principle becomes all the more central in combination with a hierarchical approach to contrast in which there is no fixed universal order of features, as has been advocated here. This is because in such an approach to contrast, phonological activity becomes our main guide as to what the contrastive features are. Some observers (p. c.) have felt that this connection

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[26] However, as long as [dental] is ordered ahead of [continuant], it is possible to do away with [nasal] as a contrastive feature in NZ Māori without affecting the adaptation patterns in (43) and (47).

between activity and contrast has a circular flavour: we use activity as a guide to the contrastive feature hierarchy (28b), and then observe, in most cases, that only contrastive features are active, in accord with the Contrastivist Hypothesis (28a). But there is no pernicious circularity here: the definition of contrast does not mention activity, and the definition of activity does not refer to contrast. Contrastive features are assigned by a feature hierarchy operating over the phonemes of a language's phonological inventory. The number of phonemes and ordering of the features determine the number of contrastive specifications that a language can have, independently of how much activity we can detect.

According to (3), a feature is active if it plays a role in the phonological computation. Clear examples are features that are involved in vowel harmony or other types of phonological assimilation; or that are needed to express a pattern of alternation, or to unite phonemes that act as a class in the phonology. In none of these cases do we need to refer to the contrastive status of a feature in deciding if it is active.

As mentioned above in connection with the definition of activity in (3), Clements's (2001) definition of feature activity contains a clause to the effect that a feature is active "if it is required for the expression of lexical contrasts". This wider definition of activity can be defended in the sense that all contrastive features are part of the phonological computation. However, this formulation mingles the definitions of activity and contrast, and creates a form of 'activity' that does not help us (as analysts or learners) arrive at a contrastive hierarchy.

Thus, we have a different perspective on 'activity' depending on whether or not we have determined what the contrastive hierarchy of a language is. *Before* arriving at a contrastive hierarchy, we look to activity in the narrow sense, as in (3), to give us evidence concerning which features are contrastive. This is the sense of activity that enters into the Activity Principle (1a). For example, suppose we have a three-vowel inventory /i, a, u/, and we have evidence that

/u/ causes rounding in the phonology. We would posit that /u/ has an active feature [round], and by (28b) we would hypothize that [+round] is a contrastive feature on /u/, distinguishing it from one or both of the other vowels. At this point we would look for evidence pointing to a second active feature that would allow us to complete the contrastive feature hierarchy for the vowels.

Even if we fail to find another phonological process that points to a second active feature, the need to distinguish between /i/ and /a/ requires us to posit a second contrastive feature in the phonology. Perhaps at this point, having exhausted Activity, a learner would resort to other principles to identify the second feature. Economy is no help in this situation, since an inventory of three elements will always require exactly two contrastive features. Universality might come into play, on the assumption that vowel systems commonly have at least one contrast based on height, or sonority.[27] Assuming a default preference for [low] over [high], we would conclude that the contrastive hierarchy for our hypothetical vowel system is [low] > [round]. At this point, *after* we have arrived at a contrastive hierarchy, the feature [low] is part of the phonological computation, and can be said to be 'active' in the wider sense of Clements (2001).

In the situation described above, we do not have *enough* evidence of activity to account for all the distinctions in a phonemic inventory. The type of case that is problematic for the Contrastivist Hypothesis, however, is a case where there is *too much* activity relative to the number of contrasts that an inventory can support, what Nevins (this volume) calls the 'Oops, I need that' (OINT) problem. Such cases are easy to construct. To continue with our example of a

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[27] Jakobson & Halle (1956) propose that, in vowel systems, a contrast between high and low sonority (vowel height) is preferably ordered before one based on place. Similarly, Steriade (1987) proposes that a contrast based on stricture features (vowel height or consonant manner) precedes one based on content features (vowel timbre or consonant place); see Ghini 2001 for a different view.

three-vowel language, suppose we find that /u/ causes rounding, /a/ causes lowering, and /i/ causes fronting; then we would have evidence for three active features (say, [round], [low], and [front]). This is an OINT problem, because three vowels allow for only two contrastive features.[28] Such a case is a *prima facie* counterexample to the Contrastivist Hypothesis. In principle there is no limit to how much activity we might find in a language; therefore, if most cases are consistent with the Contrastivist Hypothesis, then this is an empirical result, and does not follow from the definition of activity.

The feeling that the connection between activity and the contrastive feature hierarchy is suspiciously circular may have its origin in comparison with the competing approach of pairwise comparison (24) or minimal contrast (25) mentioned above in §6. In this approach, once a set of potential features has been chosen (a 'full specification' of the features), there is no variation in the contrastive specifications. Thus, familiarity with this approach to contrast might give one the impression that contrastive specifications should somehow be obvious from inspection of the inventory. Unfortunately, this method demonstrably fails in many types of cases to produce a coherent set of contrastive specifications, and is simply incorrect, as argued at length by Dresher (2009: 19–29). Further, as mentioned above, as early as 1936 Trubetzkoy observed that the set of oppositions (contrasts) in a given inventory can be construed in different ways and "depends on one's point of view"; the correct solution, however, "is implied by the system", that is, indicated by patterns of phonological activity. Therefore, reliance on the Activity Principle is not a trick to defend the Contrastivist Hypothesis, but a logical necessity: until some better method comes

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[28] This is true in the common situation where the vowels form a contrastive subset of their own, distinguished relatively high in the hierarchy from the consonants. If the vowels are evaluated as part of a larger set, together with some consonants, then they could be assigned more contrastive features.

along, phonological activity remains our best guide to the correct set of contrastive specifications.

These considerations are highly relevant to determining the empirical validity of the Contrastivist Hypothesis. As mentioned in §8, Clements (2001) concluded that the Contrastivist Hypothesis (not under that name) is too strong, because there are counterexamples in which non-contrastive features are active in the phonology. However, because Clements did not consistently follow the Activity Principle, it is possible that the counterexamples he found are only apparent, the result of assuming the wrong set of contrastive features.[29]

As with any theory, we should expect that there will be both real and apparent counterexamples to the Contrastivist Hypothesis. Thus, it is a good thing that OINT problems arise, because they allow us to refine either the hypothesis itself or other parts of phonological theory. One class of interesting cases involves the border between the phonology proper and a post-phonological phonetic component.[30] In any theory that limits the phonology proper to compute only contrastive features, there must be one or more components in which non-contrastive phonetic detail is added. MCS adopts Enhancement Theory (Stevens, Keyser & Kawasaki 1986; Stevens & Keyser 1989; Keyser & Stevens 2001, 2006), whereby the

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[29] See Dresher 2012, 2013, for discussion of an apparent counterexample to the Contrastivist Hypothesis posed by Nevins's (2010) analysis of vowel harmony in two dialects of Yoruba; see also Nevins (this volume) for a reply. Whatever the ultimate resolution of this issue, the point is that we cannot take for granted that the two dialects of Yoruba have the same contrastive specifications.

[30] In the theory of Lexical Phonology and Morphology (Kiparsky 1982, 1985; Kaisse and Shaw 1985; Mohanan 1986), this is often taken to be the boundary between the Lexical Phonology and the Postlexical Phonology.

contrastive features of a segment are made more salient by the addition of phonetic properties that enhance their acoustic effects.[31] Since it is not always easy to tell if a particular process is phonological or phonetic, the existence of enhancement (and the post-phonological addition of phonetic detail more generally) provides a source of apparent OINT counterexamples to the Contrastivist Hypothesis.

11. Conclusion

Next to the many other important contributions that Roman Jakobson, Morris Halle, and Nick Clements have made to phonological theory, and in particular, to the theory of features, their research on feature hierarchies may not immediately come to the fore. I believe, however, that feature hierarchies have not yet revealed their full potential to illuminate the synchronic and diachronic patterning of phonological systems. In the words of Jakobson, Fant & Halle (1952: 9): "The dichotomous scale is the pivotal principle of the linguistic structure. The code imposes it upon the sound." The groundbreaking studies of Jakobson, Halle, and Clements clear a path to the further exploration of this aspect of phonological theory.

I have argued that contrastive feature hierarchies are the correct way to compute contrastive features, and that hierarchies may vary cross-linguistically. In the face of this variation we require criteria to guide us as to what the correct hierarchy is in any given language. I have shown that three criteria have been prominent at different times: Activity, Minimality, and Universality. I have argued that Activity is the only reliable guide to contrastive feature hierarchies; phonological activity is the original motivation for assuming that contrastive features

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[31] See Dyck 1995 and Hall 2011 for detailed studies of enhancement within the MCS framework; see also Kim 2013 for a complex case of allophony in Huave that presents an interesting challenge to the Contrastivist Hypothesis.

have a special role to play in the phonology. By contrast, Minimality and Universality remain empirical hypotheses, and it is already clear that they represent tendencies, at best. Moreover, in many cases they conflict: a feature ordering that respects Minimality may be at odds with one that comes closest to Universality. And both Minimality and Universality can conflict with Activity. In these circumstances, it is best to base contrastive feature hierarchies on Activity, and then see to what extent these hierarchies adhere to Minimality and Universality.

Finally, I have argued that a consistent adherence to Activity and a hierarchical approach to contrast puts the Contrastivist Hypothesis into a different light, by reducing the number of apparent counterexamples that arise in other approaches. This hypothesis, which Clements (2001) had to give up despite finding that it is 'interesting', 'strong', and 'attractive', might yet turn out to be substantially true, and a reliable principle of synchronic and diachronic phonological patterning.

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B. Elan Dresher

Department of Linguistics

100 St. George Street, Room 4073

University of Toronto

Toronto, Ontario

Canada M5S 3G3

dresher@chass.utoronto.ca

(2) Branching diagram Figure I–1 (Halle 1959: 46)