CUNY PHONOLOGY FORUM

CONFERENCE ON THE FEATURE

January 16–18, 2013

Morris Halle, Nick Clements, and the Role of Feature Hierarchies in Phonology

B. Elan Dresher
University of Toronto

Introduction

Both Morris Halle and Nick Clements have made fundamental contributions to the theory of features in phonology.

Interestingly, both have, independently and at different times, proposed that features are organized into hierarchies.

Feature hierarchies first became prominent in phonological theory in Halle's work with Roman Jakobson and their colleagues (Jakobson, Fant & Halle 1952; Cherry, Halle & Jakobson 1953; Jakobson & Halle 1956), where they took the form of 'branching trees'.

Introduction

A branching tree of this kind appears in Halle's *The sound pattern of Russian* (*SPR,* 1959); but by the time of *The sound pattern of English* (*SPE,* Chomsky & Halle 1968), feature hierarchies played at best a minor role in phonological theory.

Over forty years later, feature hierarchies reappeared in the work of Clements in the form of an 'accessibility scale' (Clements 2001) and later as a 'robustness scale' (Clements 2009).

I will consider their work on feature hierarchies in the context of developments in phonological theory. My main focus will be on the motivation for feature hierarchies.

Introduction

I will show that they have been motivated by different principles:

A. to minimize redundancy in phonological representations and to maximize the amount of information conveyed by each feature;

B. to express universal tendencies in the nature of phonological inventories and the order of acquisition of feature contrasts;

C. to account for the patterns of activity of features in the phonologies of languages.

Introduction

These principles do not necessarily conflict in theory, but in practice situations arise where they lead in different directions.

To some extent both Halle (1959; Jakobson & Halle 1956) and Clements (2001; 2003a; b; 2009) appeal to all these principles, though they do so with differing emphases:

Halle came to stress principle A (minimize redundancy),

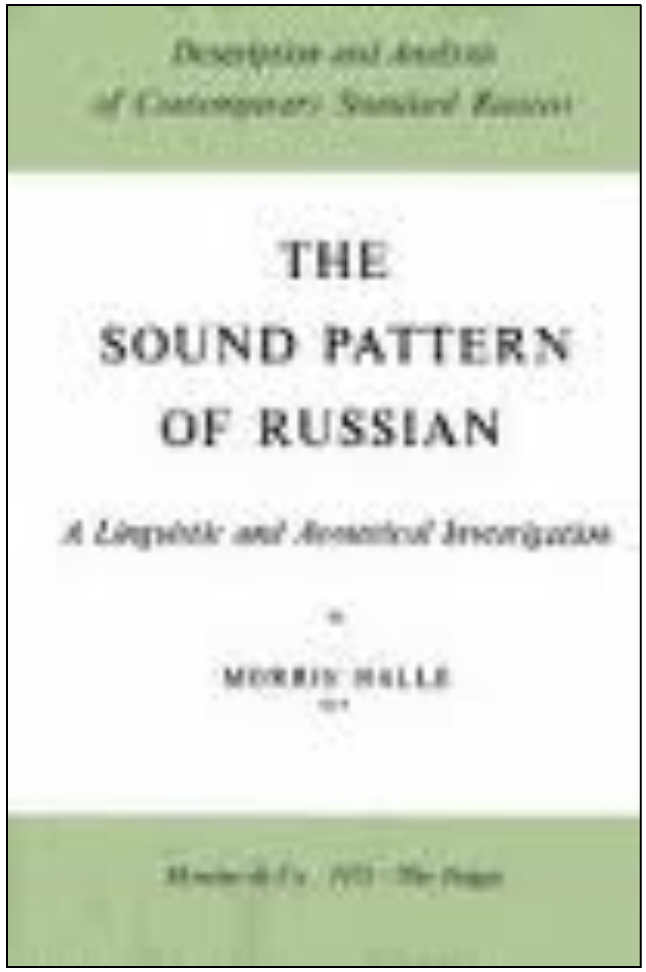
Clements focused on principle B (universal tendencies).

I will argue on behalf of the centrality of principle C (account for patterns of phonological activity).

Halle (1959):

The ‘Branching Tree’

On p. 46 in *The sound pattern of Russian* is Figure I–1, a magnificent tree diagram that shows the contrastive feature specifications of every phoneme of Russian.



On p. 46 in *The sound pattern of Russian* is Figure I–1, a magnificent tree diagram that shows the contrastive feature specifications of every phoneme of Russian.

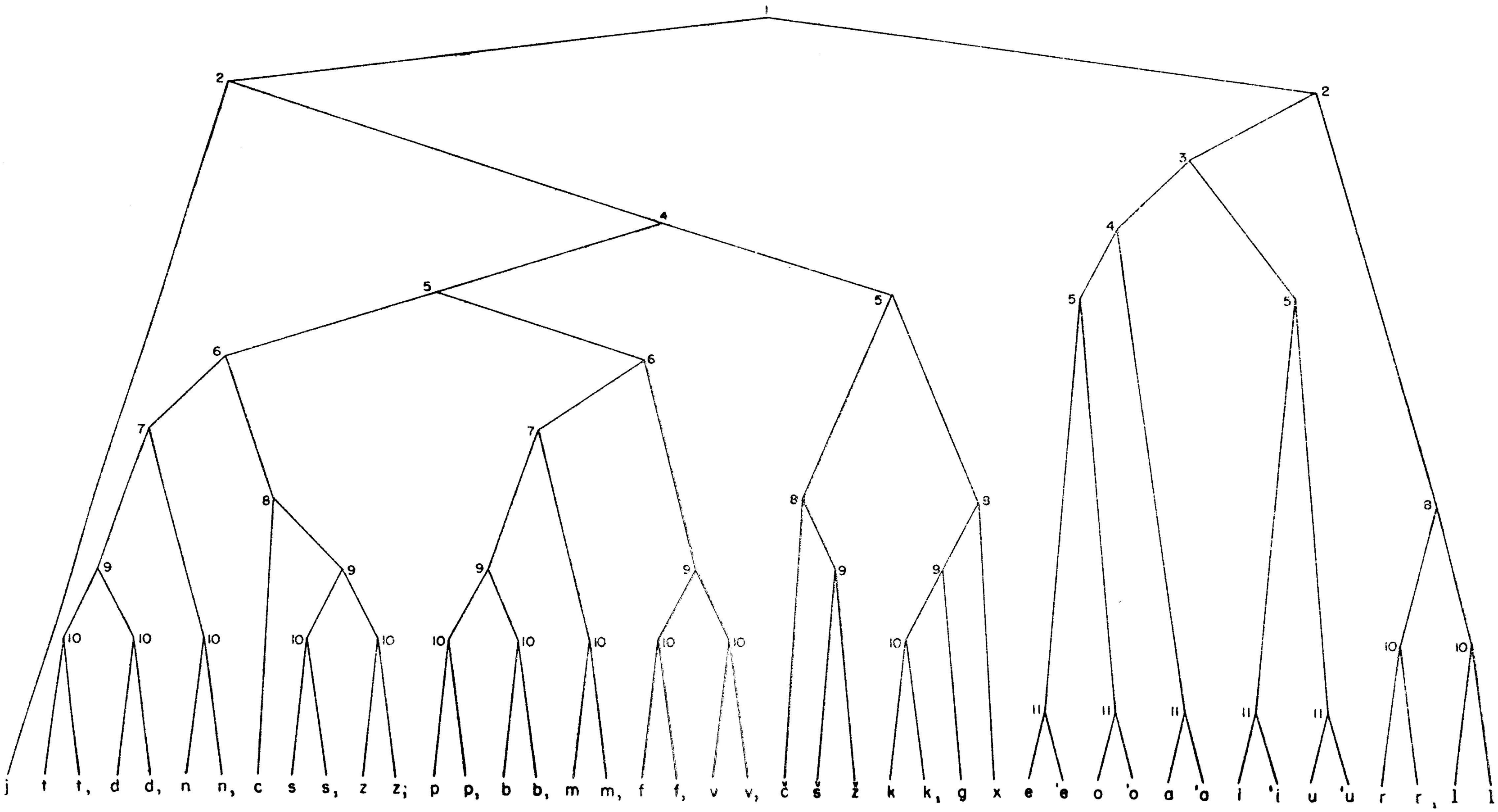
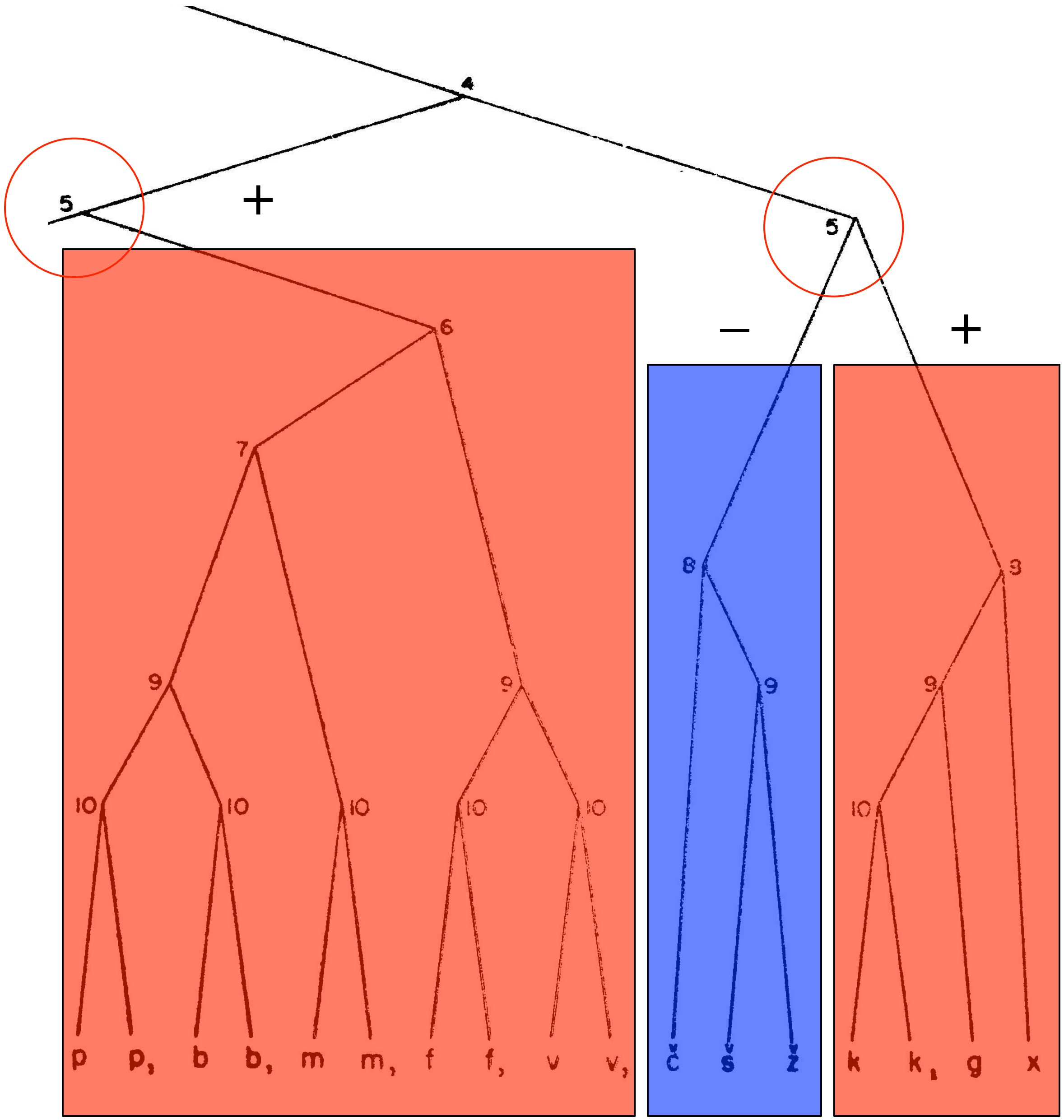


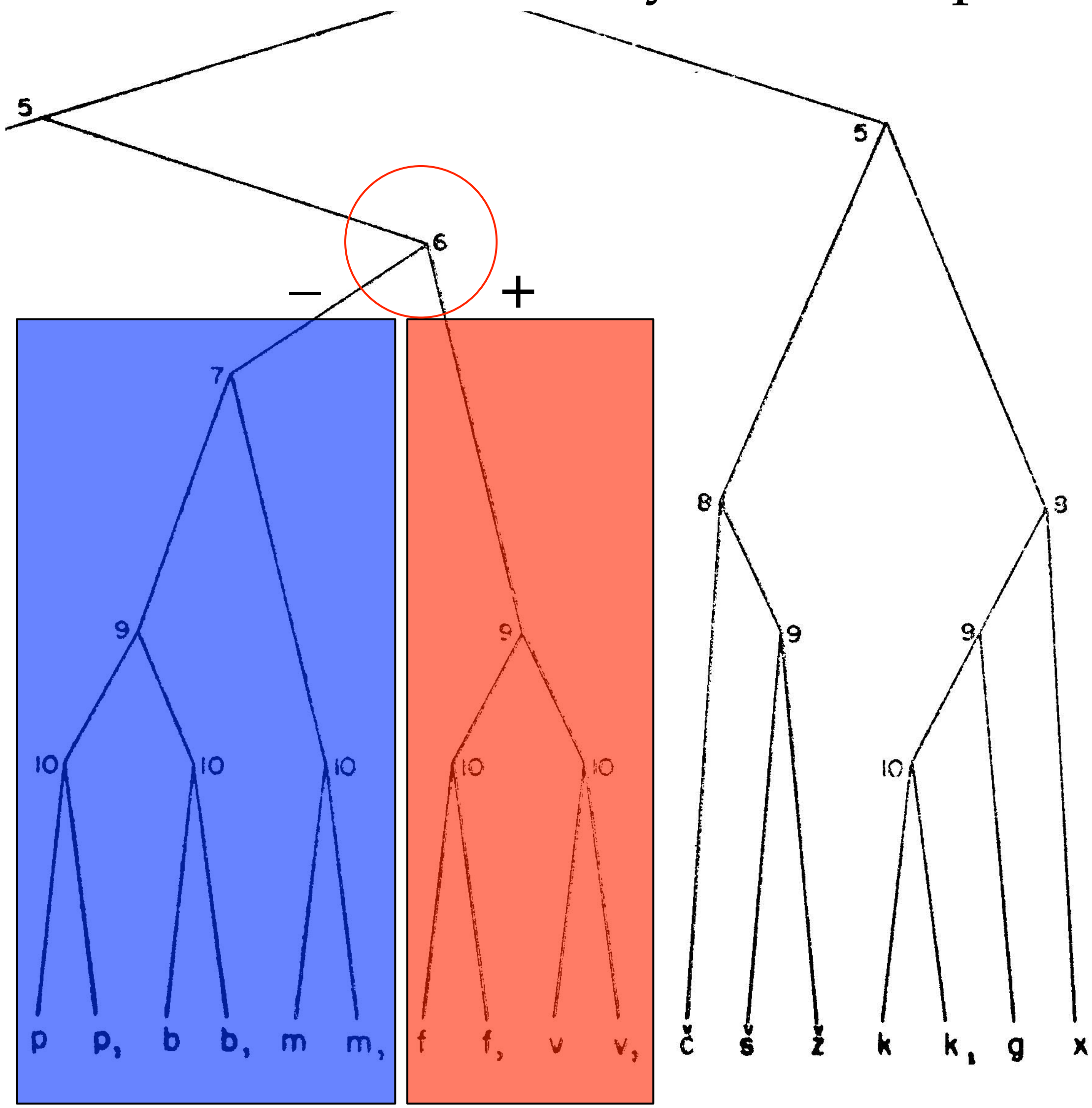
Fig. I-1. Branching diagram representing the morphonemes of Russian. The numbers with which each node is labelled refer to the different features, as follows: 1. vocalic vs. nonvocalic; 2. consonantal vs. nonconsonantal; 3. diffuse vs. nondiffuse; 4. compact vs. noncompact; 5. low tonality vs. high tonality; 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.

Feature 5, for example, stands for [low tonality] (aka [grave]).



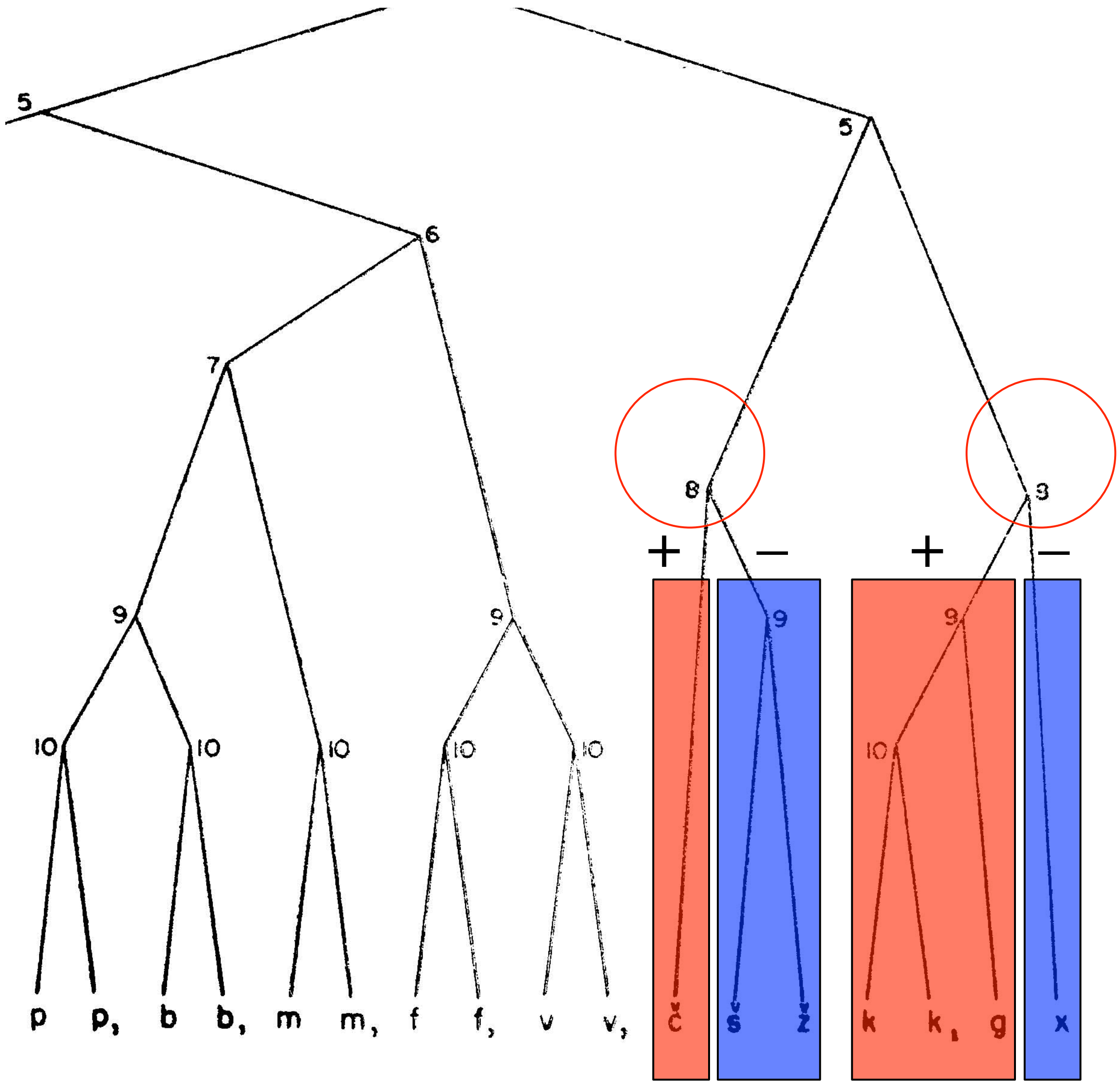
5: [low tonality]:
+ = labials, velars
– = coronals

Feature 6 stands for [strident]. Here it applies within the labials to distinguish the fricatives from the stops. It does not apply to *č, š, ž* because these already form a separate group.



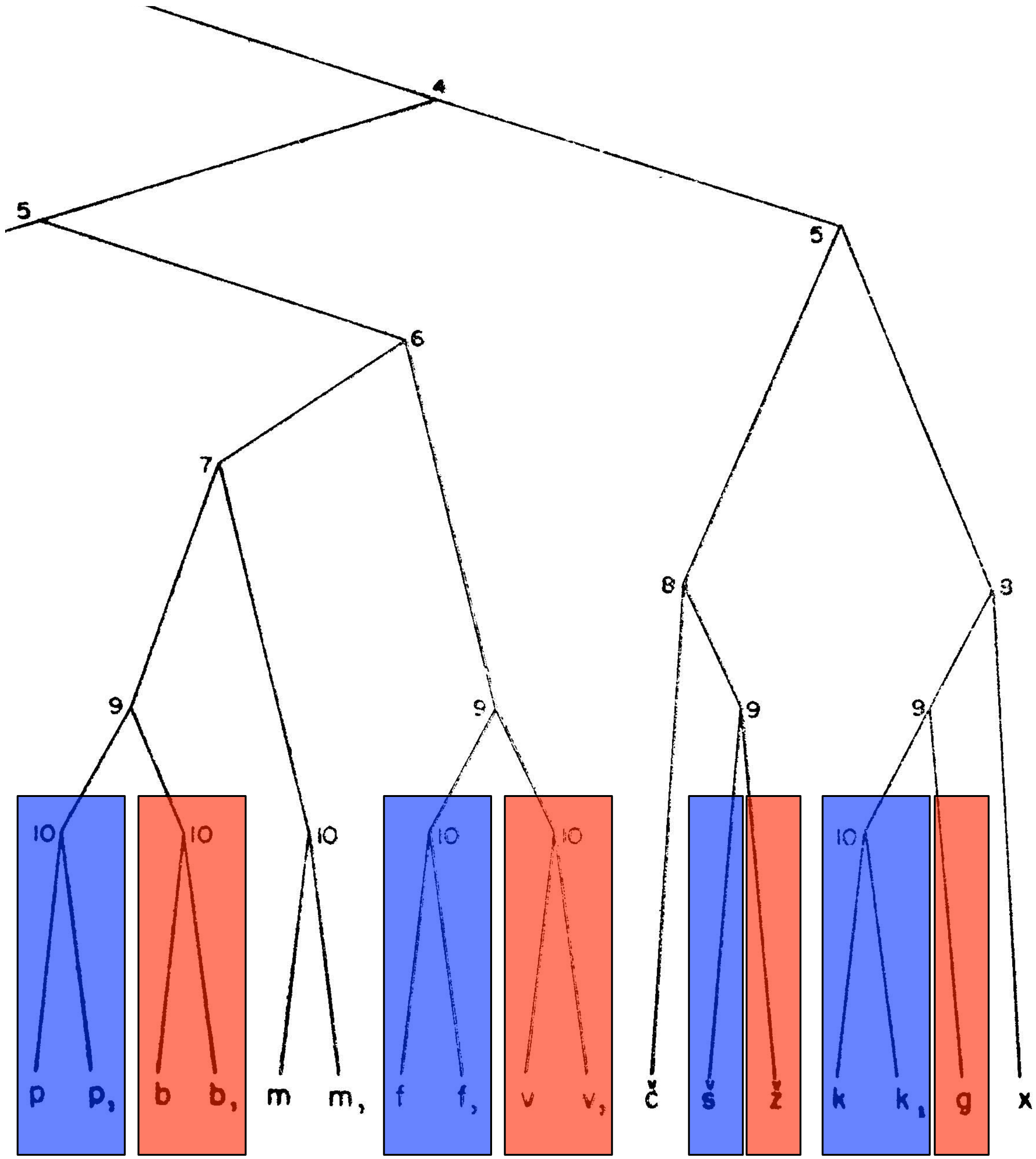
6: [strident]:
– = mellow
+ = strident

Feature 8 is [continuant]. It does not apply to the labials because the stops and fricatives have already been distinguished by [strident].



8: [continuant]:
– = interrupted
+ = continuant

Feature 9 is [voiced]. It does not apply to nasals, *č*, and *x*.



9: [voiced]:

\+ = voiced

– = voiceless

Origins of the Branching Tree

The tree has antecedents in the work of Roman Jakobson and his collaborators. A tree of this kind underlies the feature specifications in an article on Standard French by Jakobson and John Lotz (1949).

I say 'underlies' because the tree itself does not appear. However, their representations are consistent with such a tree, and are difficult to explain otherwise.

Origins of the Branching Tree

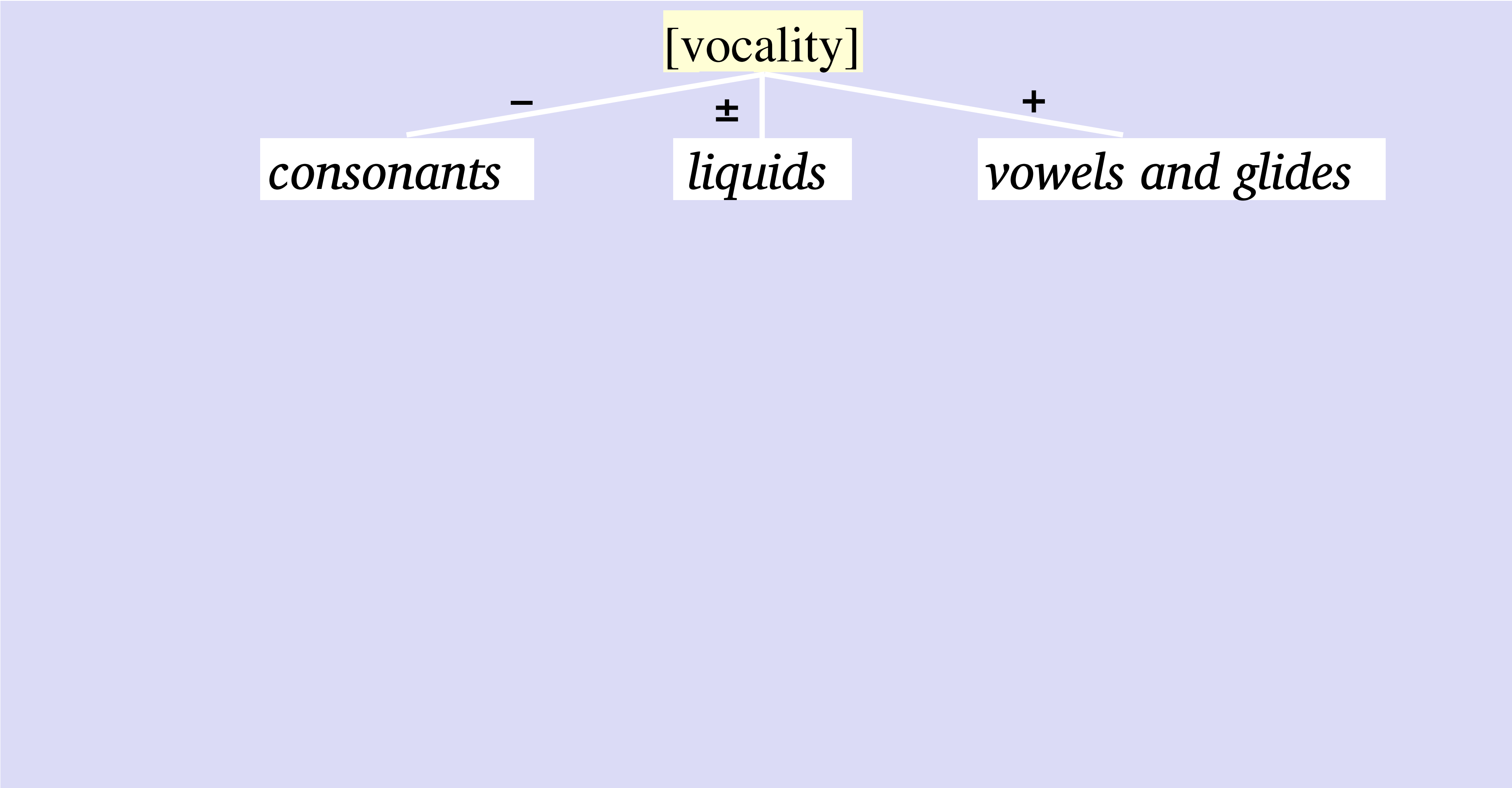
The tree appears overtly in Jakobson, Fant and Halle (1952). They propose that listeners identify phonemes by distinguishing them from every other phoneme in the system.

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.

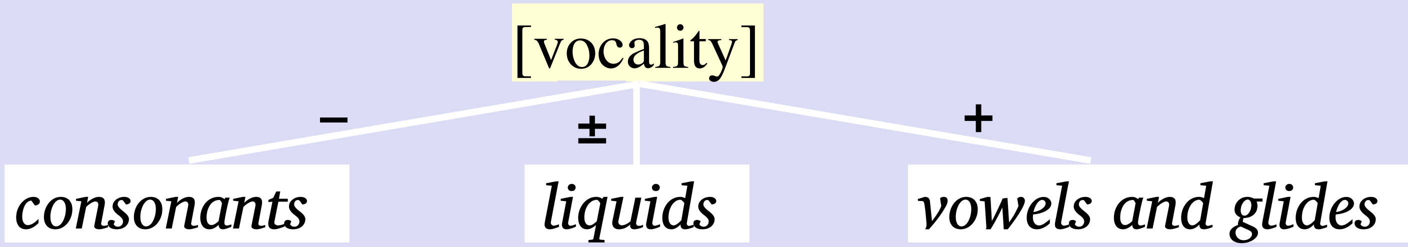
On this approach, the *ordering* of the features is crucial: different orders result in different specifications.

Decision Tree for Standard French



Returning to the analysis of Jakobson and Lotz (1949), the first decision pertains to [vocality]: phonemes are either – (consonants), + (vowels and glides), or a third value, ±, for liquids.

Decision Tree for Standard French

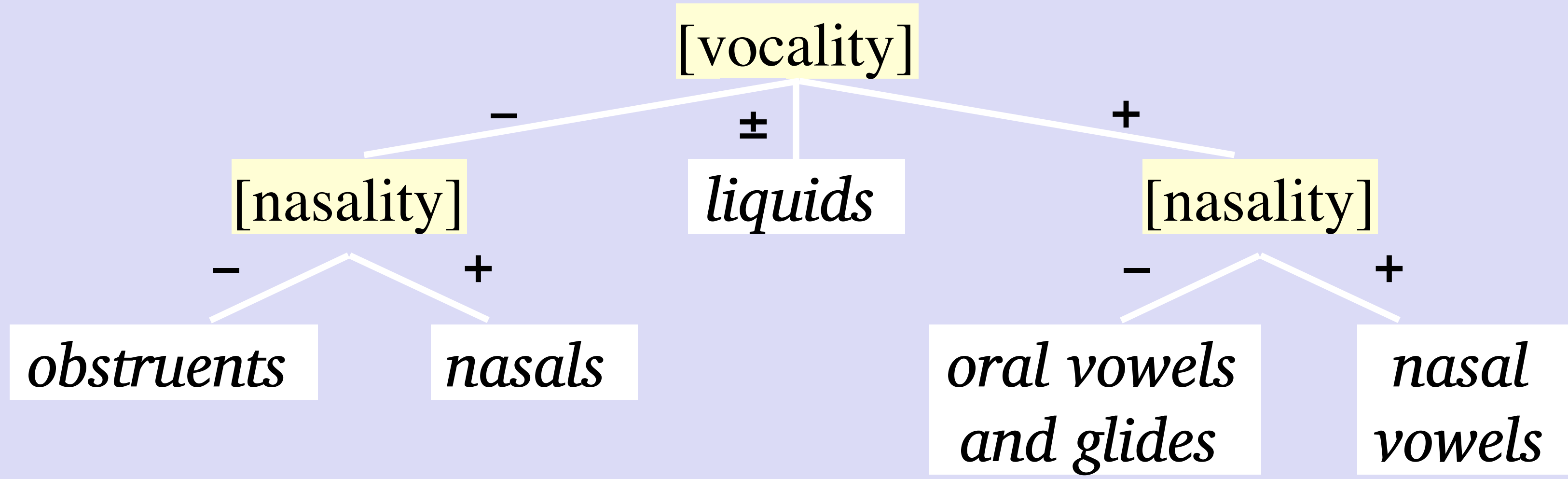


[vocality] > [nasality] > [saturation] >

[gravity] > [tensity] > [continuousness]

Jakobson and Lotz assume the ordering shown above. Each feature applies in turn to each branch of the inventory in which it is contrastive.

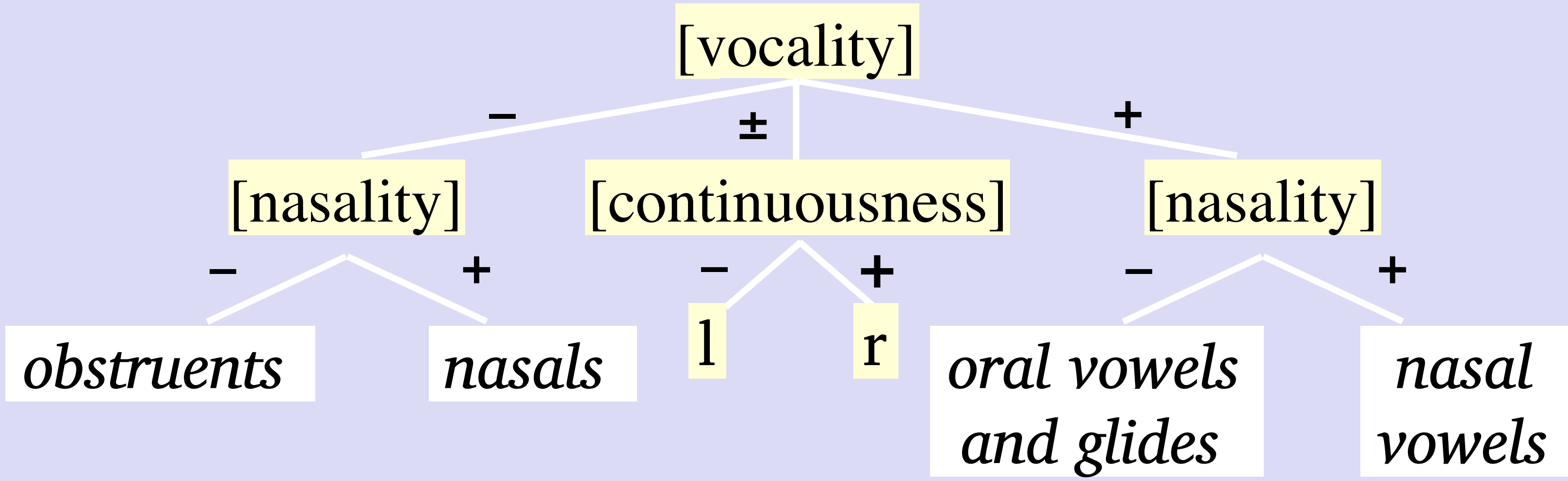
Decision Tree for Standard French



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

The second feature to apply is [nasality]. It is contrastive in the consonants and vowels, but not among the liquids.

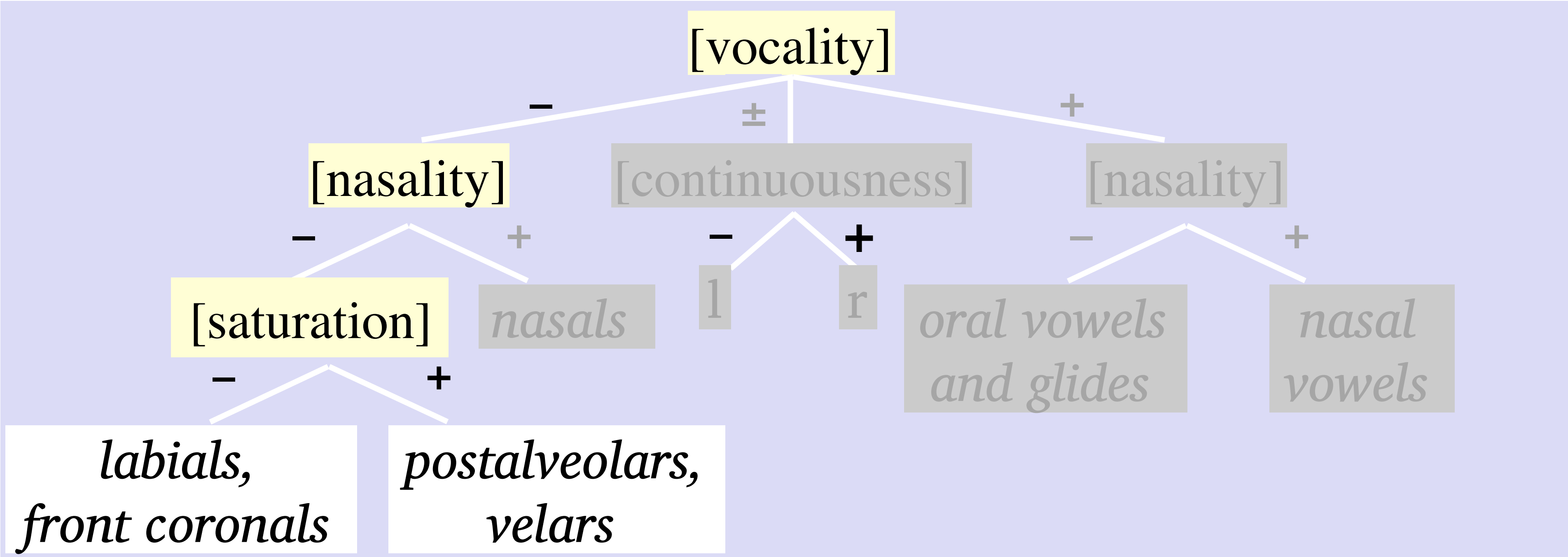
Decision Tree for Standard French



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

If a feature is not contrastive in a branch, it is not assigned. For example, there are only two liquids, /l, r/, and only the last feature, [continuousness], distinguishes them.

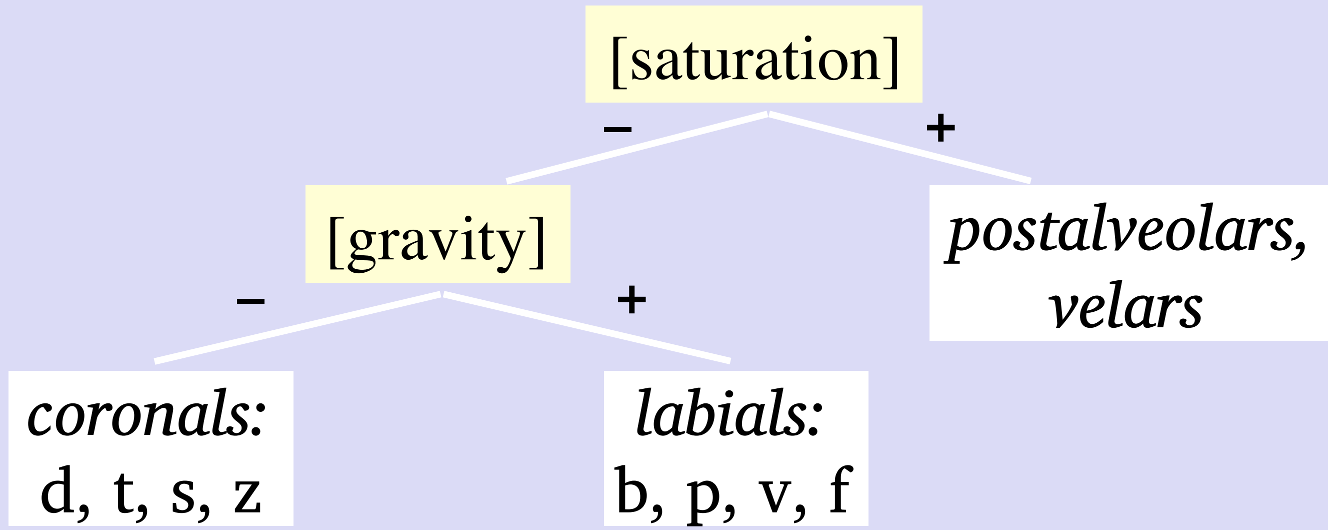
Decision Tree for Standard French



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

Continuing this example, suppose we have chosen [–vocality] and [–nasality]. The next choice is [saturation]: either unsaturated (labials and front coronals) or saturated (postalveolars and velars).

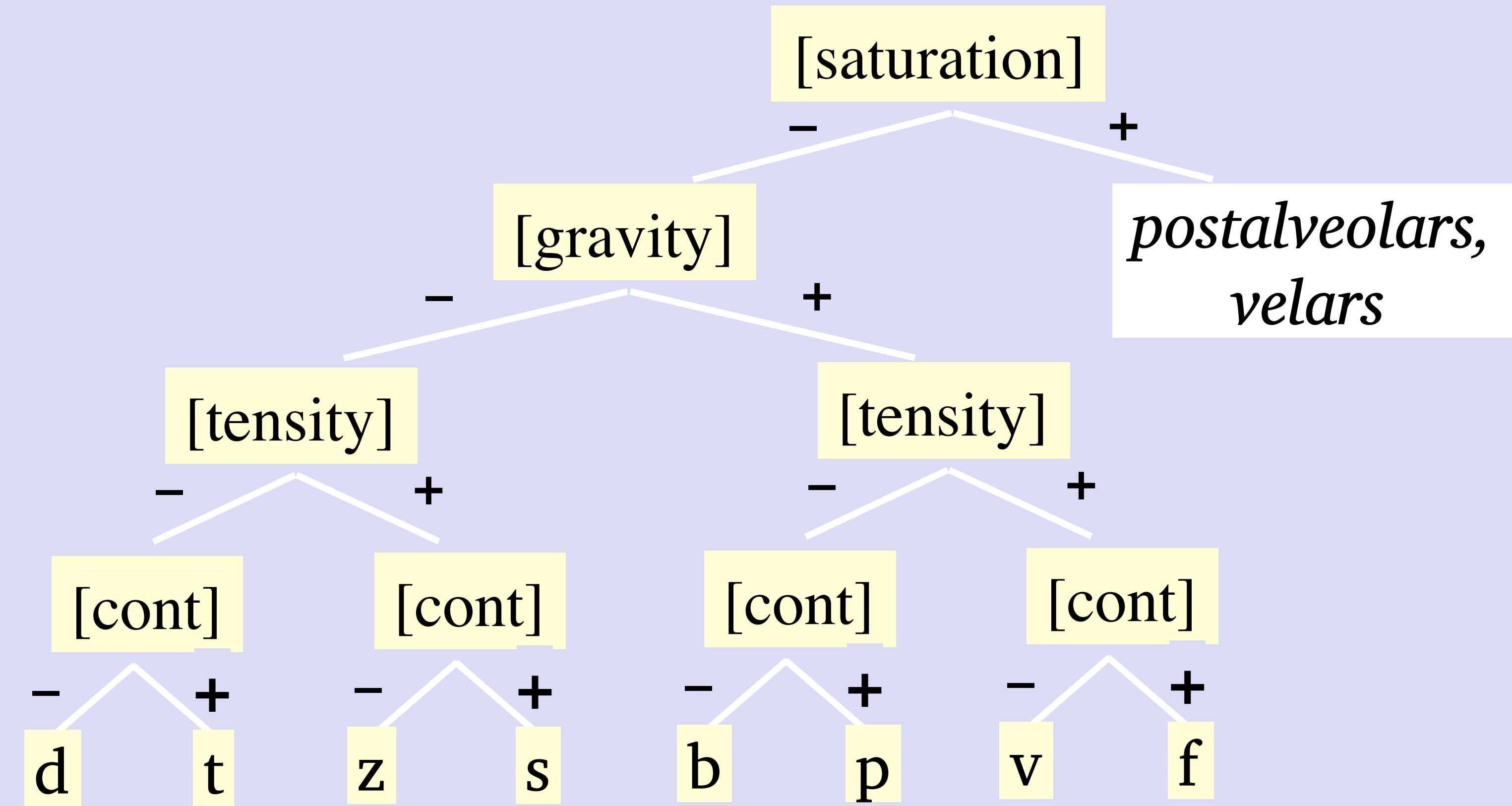
Decision Tree for Standard French



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

If we choose [–saturation], the next feature is [gravity]: coronals are – and labials are +.

Decision Tree for Standard French



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

The final choices are [tensity] (like [voiceless]) and [continuousness] in each branch.

Prague School Phonology: The role of contrastive properties

Contrastive Properties are Active

An idea that can be traced to the beginnings of modern phonology is that only some properties of a segment are *active*, or *relevant* (Trubetzkoy), to the phonology, and these are the distinctive, or contrastive, properties.

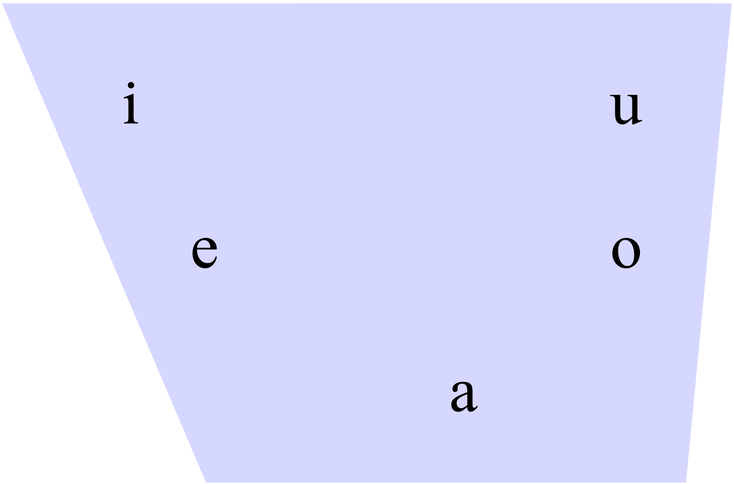
An early expression of this idea can be found in Jakobson's (1962 [1931]) discussion of the difference between the Czech and Slovak vowel systems.

Czech and Slovak Vowel Systems

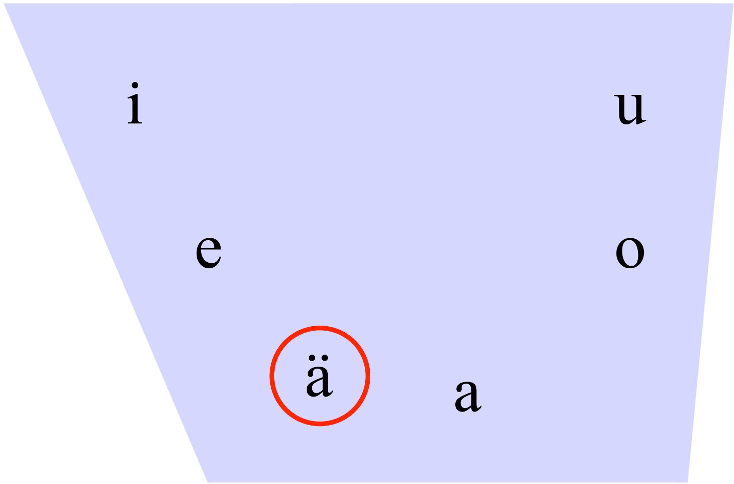
Jakobson cites the observation of B. Hála that the simple vowels of Slovak "correspond completely both in their production and in the auditive impression they produce to the vowels of Standard Czech"…

…except for a short front vowel *ä* that occurs in dialects of Central Slovak.

Czech



Central Slovak

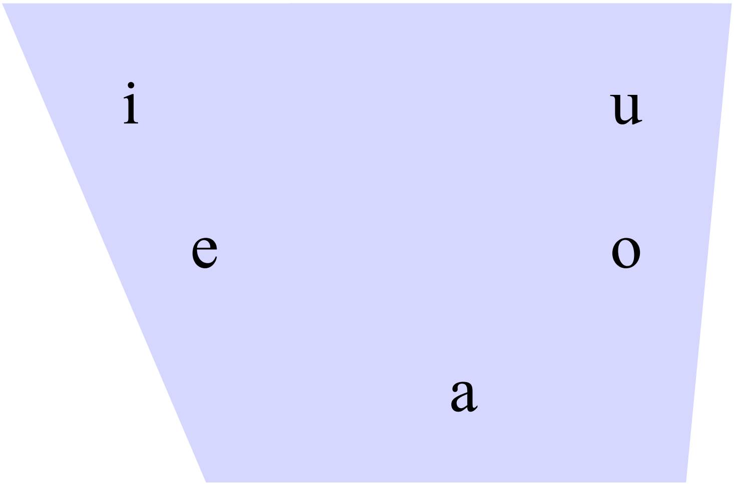


Czech and Slovak Vowel Systems

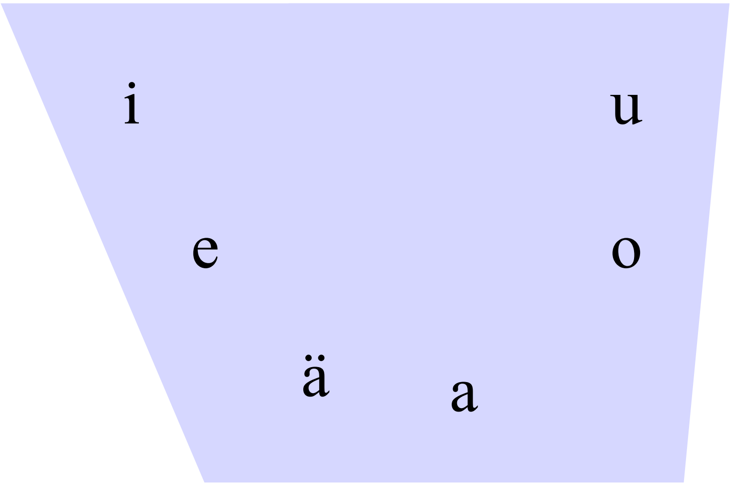
Jakobson notes that the presence of *ä* in Slovak, though "a mere detail from a phonetic point of view ... determines the phonemic make-up of all the short vowels."

The 'phonemic make-up' of a vowel phoneme can be equated with its contrastive properties.

Czech



Central Slovak



Czech and Slovak Vowel Systems

Jakobson diagrams the Czech and Slovak short vowels as below:

The Slovak front-back contrast in the low vowels sets up a parallel contrast in the non-low vowels.

Central Slovak

	Front	Back
High	i	u
Mid	e	o
Low	ä	a

Czech and Slovak Vowel Systems

In Czech, the low vowel has no contrastive tonality feature.

In the non-low vowels the back/round dimensions are fused (cf. Kaye, Lowenstamm and Vergnaud 1985).

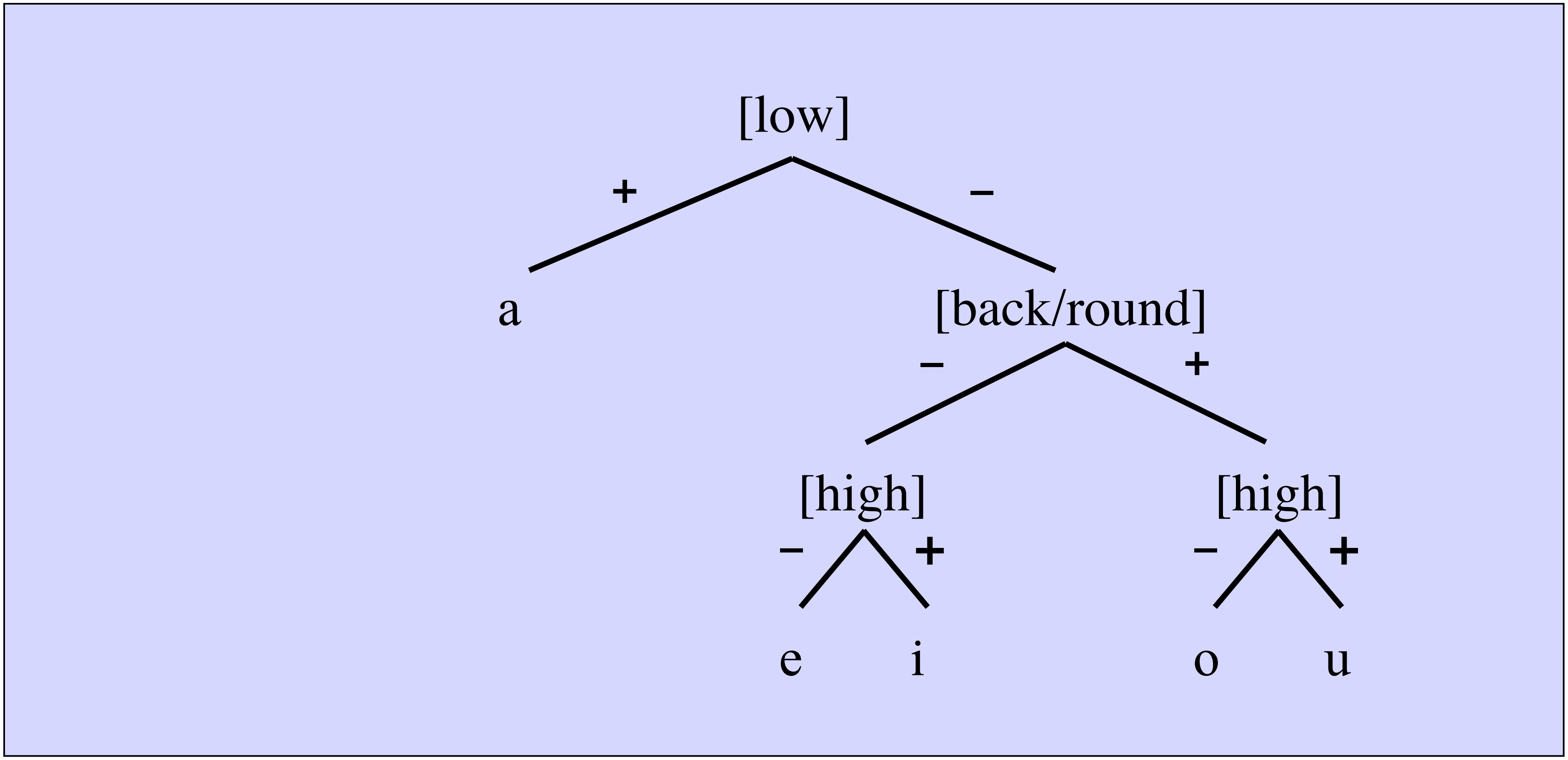
Czech

	Front/unround	Back/round
High	i	u
Mid	e	o
Low	a	

Central Slovak

	Front	Back
High	i	u
Mid	e	o
Low	ä	a

Contrastive Feature Ordering for Czech Vowels



Jakobson's analysis of Czech implies an ordering [low] > [back/round], [high]. This ordering *explains* why /a/ has no tonality features.

Other Five-Vowel Systems

Trubetzkoy (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 an example of this kind of system.

Latin

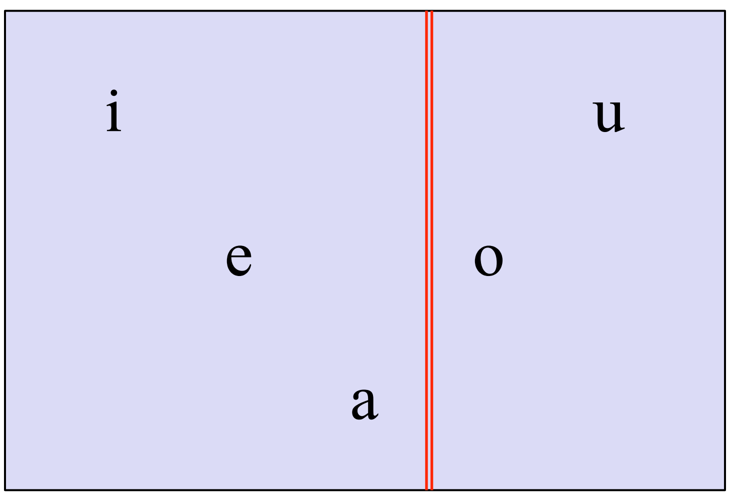
Front/unround	Back/round	
i	u	High
e	o	Mid
a		Low

Other Five-Vowel Systems

However, he observes that other types of vowel systems exist.

In 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*".

Artshi (East Caucasian)



Other Five-Vowel Systems

"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: 100-101).

This analysis corresponds to ordering [round] first, followed by [high] and [low] (the latter only in the unrounded vowels).

Artshi (East Caucasian)

Unround	Round	
i	u	High
e	o	Mid
a		Low

Other Five-Vowel Systems

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/.

Artshi (East Caucasian)

	Unround	Round
High	i	u
Mid	e	o
Low	a	

Japanese

	Front	Back
High	i	u
Mid	e	o
Low		a

Other Five-Vowel Systems

The governing opposition is that between front and back vowels, lip rounding being irrelevant.

This analysis corresponds to ordering [front] first, followed by [high] and [low] (the latter only in the back vowels).

Artshi (East Caucasian)

	Unround	Round
High	i	u
Mid	e	o
Low	a	

Japanese

	Front	Back
High	i	u
Mid	e	o
Low		a

Contrast depends on 'point of view'

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: 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.

Contrast depends on 'point of view'

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: 20)

The correct ordering is 'implied by the system', meaning, suggested by the pattern of phonological activity in the system.

The Contrastivist Hypothesis

To summarize to here, the analyses we have looked at assume what Hall (2007: 20) calls the *Contrastivist Hypothesis:*

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

It follows that only *contrastive* features can be *active* in phonological processes.

Contrast via Feature Ordering

Second, contrastive features are determined by ordering features into a *contrastive hierarchy*:

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

This method was called 'branching trees' in the literature, when referred to at all. I call it the *Successive Division Algorithm* (Dresher 1998, 2003, 2009) .

Variability of Feature Ordering

Third, we learn from the above examples that the contrastive hierarchy must allow for *variation:*

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

Rationale for Feature Hierarchies

On this view, the motivation for not listing every possible feature that could characterize a phoneme is what I have called Principle C:

Principle C

The purpose of a feature hierarchy is to identify the contrastive features that are relevant to the phonological computation.

Consider, for example, Trubetzkoy's remarks about German and Czech *h*:

Rationale for Feature Hierarchies

German /h/ stands apart from all other phonemes by being laryngeal (that is, by ordering the laryngeal feature over other features that could apply to /h/)…

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

Rationale for Feature Hierarchies

Looking at the Czech consonant inventory, one might suppose that Czech *ɦ* is similarly isolated.

However, Trubetzkoy (1969: 124) proposes that Czech *h* (or more properly, *ɦ*), forms a minimal contrast with *x*.

p		t		ts	c		tʃ	k	
b		d			ɟ			g	
	f			s			ʃ	$\boxed{x}$	
	v			z			ʒ		ɦ
m			n			ɲ			
			r			r̝			
			l						
						j			

Rationale for Feature Hierarchies

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.

p		t		ts	c		tʃ	k	
b		d			ɟ			g	
	f			s			ʃ	$\boxed{\text{x}}$	
	v			z			ʒ		ɦ
m			n			ɲ			
			r			r̝			
			l						
						j			

Rationale for Feature Hierarchies

"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". (1969: 124)

p		t		ts	c		tʃ	k
b		d			ɟ			g
	f			s			ʃ	x
	v			z			ʒ	ɦ
m			n			ɲ		
			r			r̝		
			l					
						j		

Rationale for Feature Hierarchies

That is, ɦ and x form a minimally contrastive pair in Czech, but we have to *abstract away* from differences that are not deemed to be phonologically relevant.

p		t		ts	c		tʃ	k
b		d			ɟ			g
	f			s			ʃ	x
	v			z			ʒ	ɦ
m			n			ɲ		
			r			r̝		
			l					
						j		

Rationale for Feature Hierarchies

In Czech, the laryngeal feature is ordered lower in the hierarchy, too low to be contrastive for /ɦ/. Thus, it is phonological activity that is the key to determining what the relevant contrastive features are.

p		t		ts	c		tʃ	k	
b		d			ɟ			g	
	f			s			ʃ	x	
	v			z			ʒ		ɦ
m			n			ɲ			
			r			r̝			
			l						
						j			

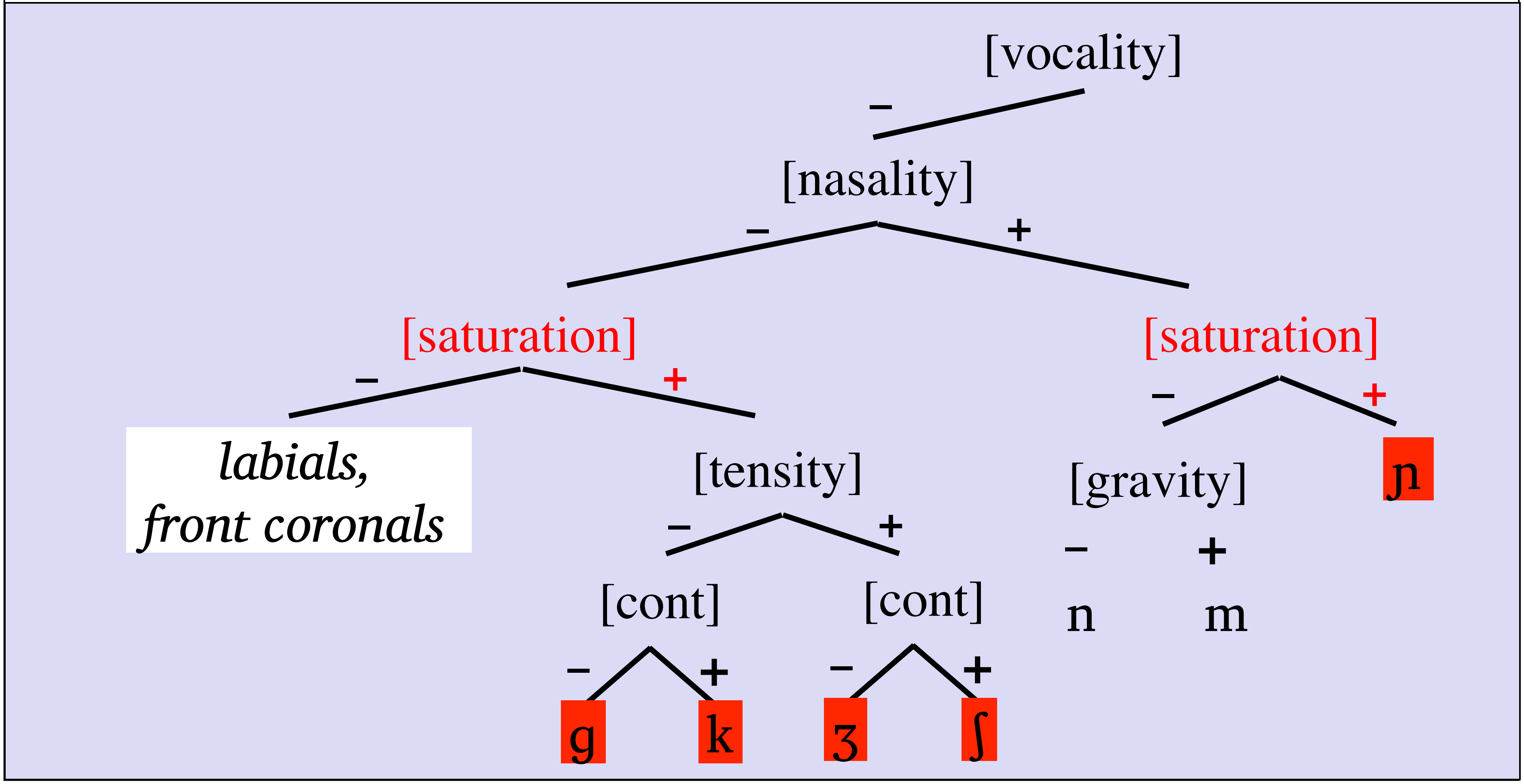
Rationale for Feature Hierarchies

Similarly, Jakobson and Lotz (1949) give empirical arguments for their choice of features for Standard French, based on two types of phonological activity:

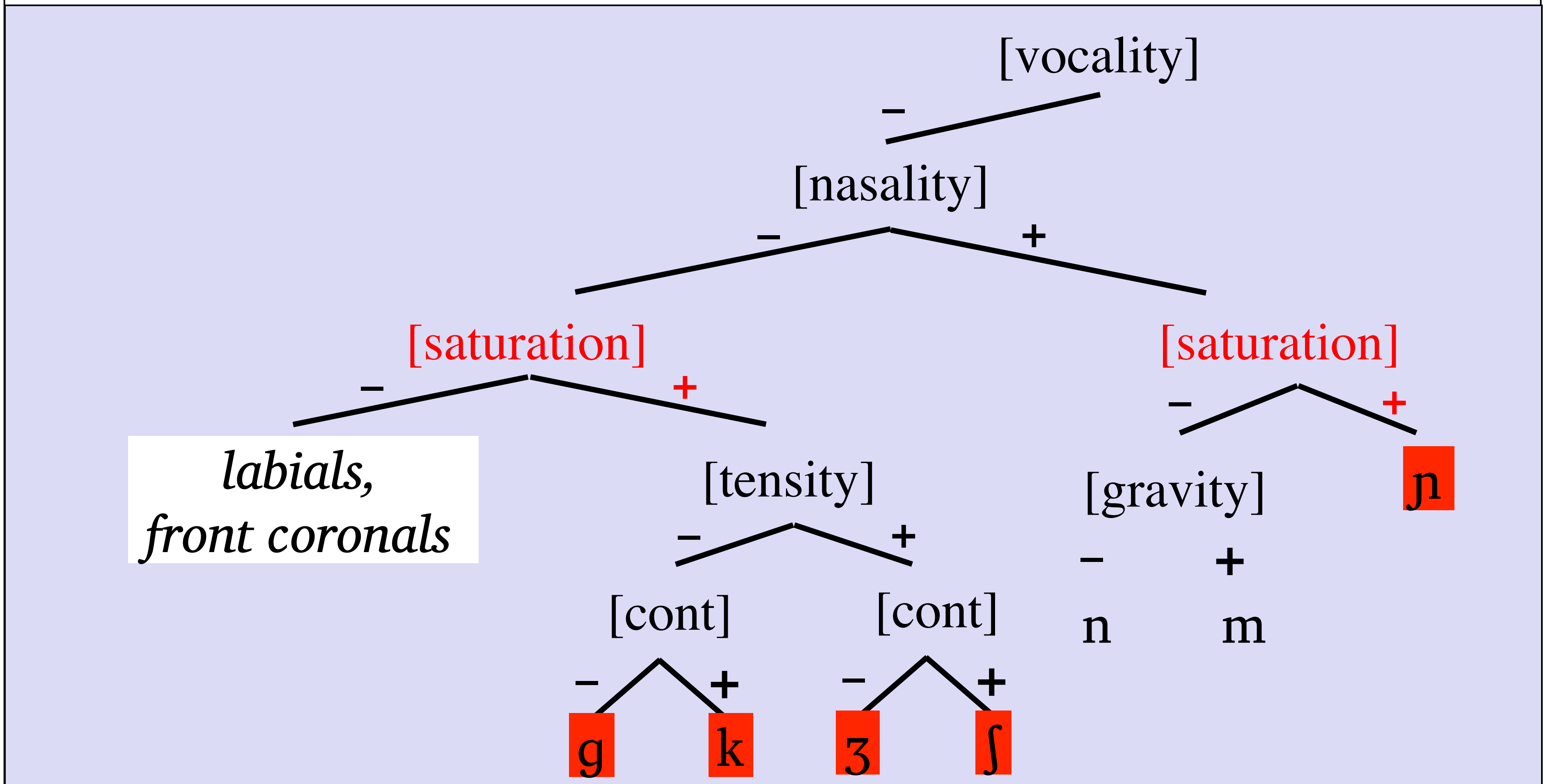
- the adaptation of foreign sounds

- language-internal alternations

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."



Halle (1959) again:

A different rationale

for contrastive features

Changing Rationales for Feature Hierarchies

Despite these antecedents, this is not the approach taken by Halle in *The sound Pattern of Russian*.

The change in rationale for limiting specifications to contrastive features is hinted at by Jakobson and Halle (1956), when discussing Standard French.

Though their analysis is similar to that of Jakobson and 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.

Changing Rationales for Feature Hierarchies

In the 1950s, Jakobson and Halle became interested in the then-new field of information theory, and began to look at branching trees as a way of conveying information about phonemes in the most economical way (cf. Cherry, Halle and Jakobson 1953).

This criterion, Principle A, came to overshadow the earlier one, what I have called Principle C, that is, to reflect the active features and account for phonological patterning.

Changing Rationales for Feature Hierarchies

Principle C

The purpose of a feature hierarchy is to identify the contrastive features that are relevant to the phonological computation.

Changing Rationales for Feature Hierarchies

Principle C

The purpose of a feature hierarchy is to identify the contrastive features that are relevant to the phonological computation.

Principle A

The purpose of a feature hierarchy is to to minimize redundancy in phonological representations and to maximize the amount of information conveyed by each feature.

Feature Hierarchies to Minimize Specifications

In *The sound pattern of Russian* (29–30), Halle's version of Principle A is Condition (5):

Condition (5): In phonological representations the number of specified features is consistently reduced to a minimum compatible with satisfying Conditions (3) and (4).

Roughly speaking, Conditions (3) and (4) require that the phonological description meet basic conditions of adequacy.

Feature Hierarchies to Minimize Specifications

Halle observes (*SPR*: 44–5) 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 with the lower limit of $\log_2 43 = 5.26$ specifications, which would represent the most efficiently branching tree for 43 phonemes.

Recall the tree from *The sound pattern of Russian*. We will focus on one part of it.

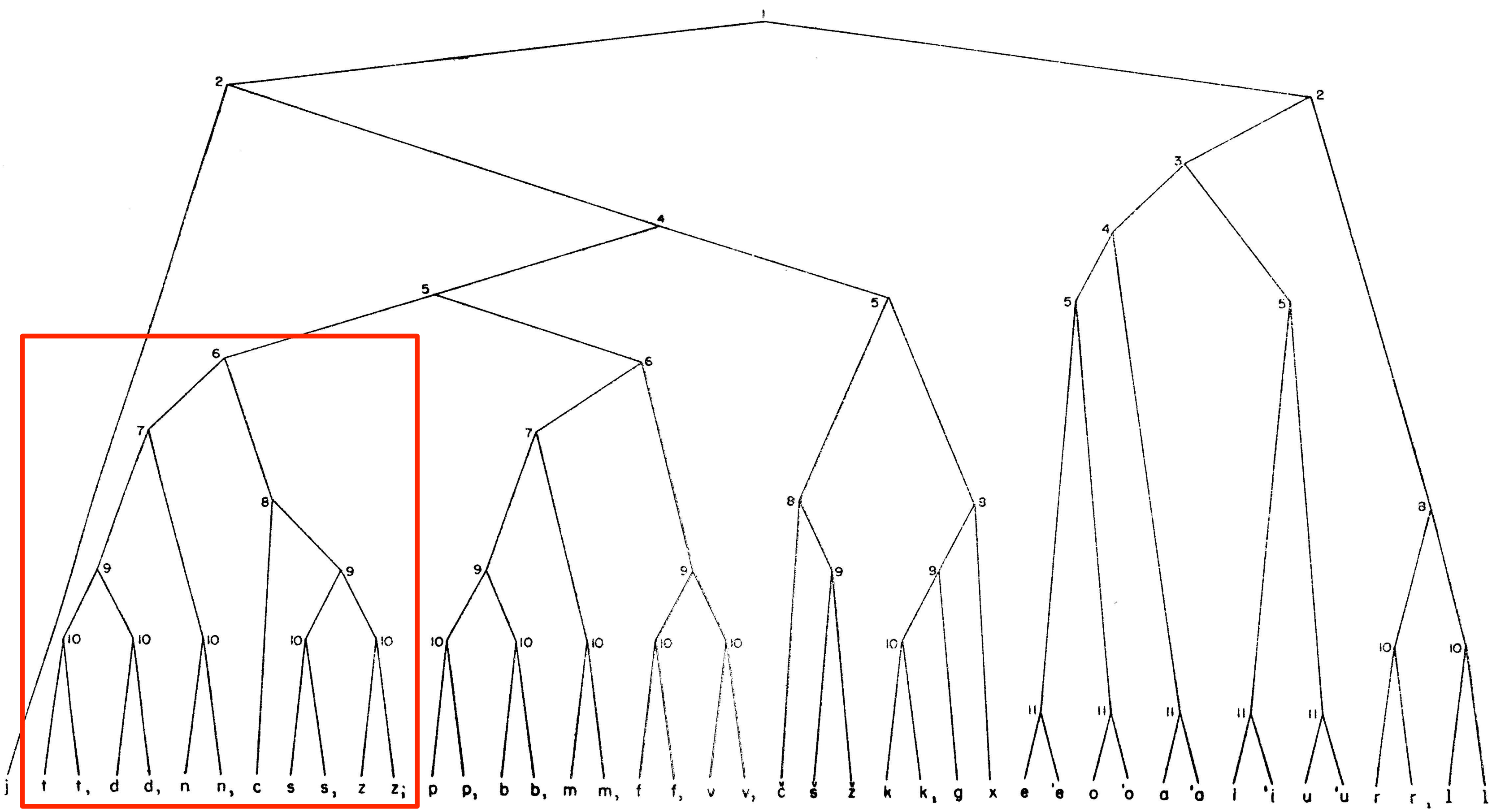
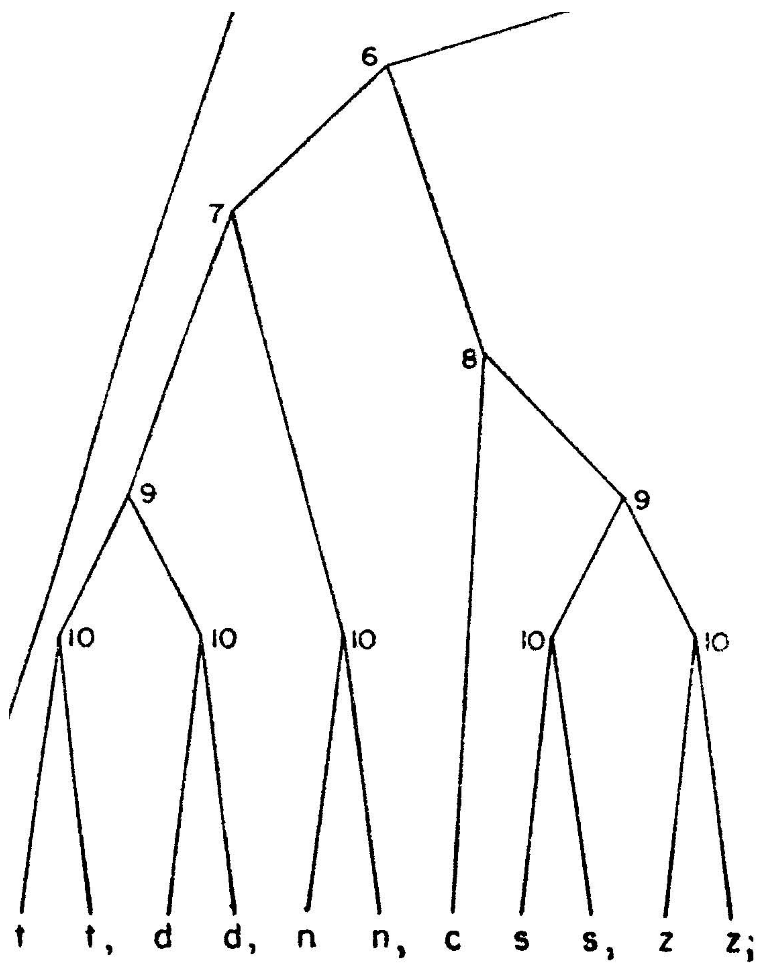
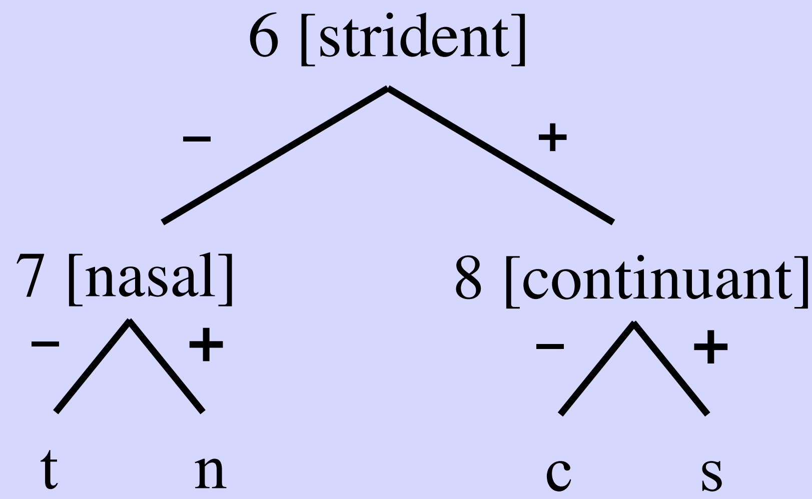


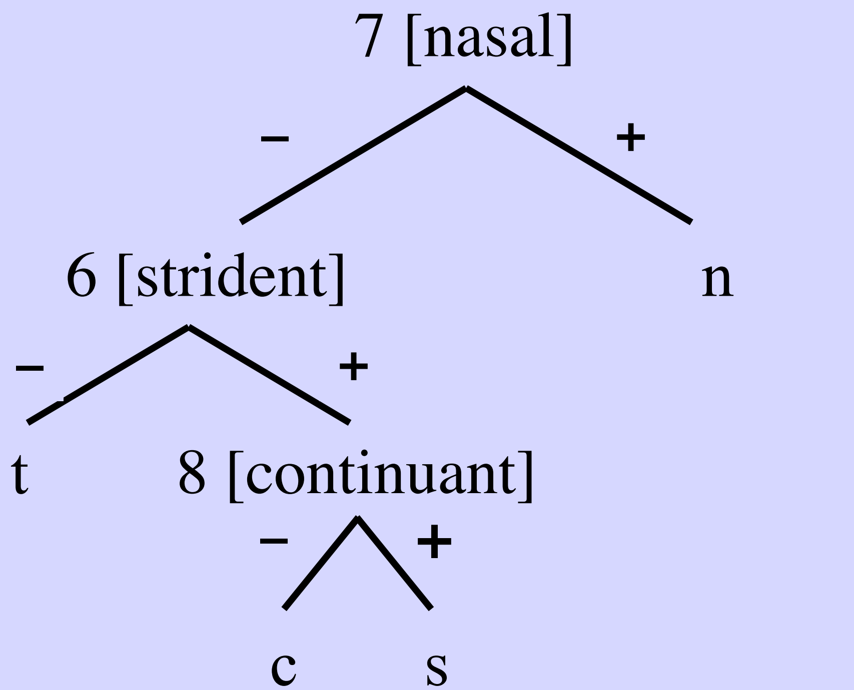
Fig. I-1. Branching diagram representing the morphonemes of Russian. The numbers with which each node is labelled refer to the different features, as follows: 1. vocalic vs. nonvocalic; 2. consonantal vs. nonconsonantal; 3. diffuse vs. nondiffuse; 4. compact vs. noncompact; 5. low tonality vs. high tonality; 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.

Condition (5) accounts for the somewhat unintuitive ordering of [strident] (feature 6) > [nasal] (7). A simplified diagram illustrating selected phonemes is shown below on the right.

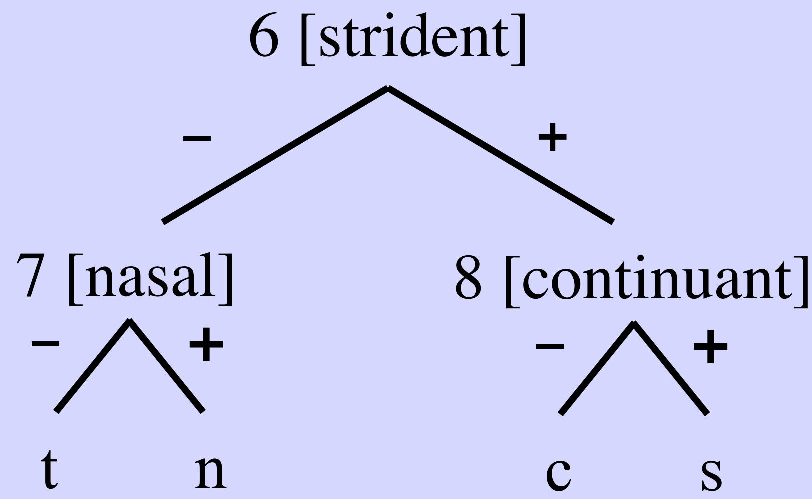




In the tree on the left nasals are not within the scope of [strident]. However, this tree is less symmetrical and requires more specifications. Condition (5) prefers the *SPR* ordering.



Alternate: 4 phonemes, 9 specs, = 2.25 specs per phoneme.



SPR: 4 phonemes, 8 specs = 2.00 specs per phoneme = $\log_2 4$.

The ordering in another part of the the tree had momentous consequences for the development of phonological theory.

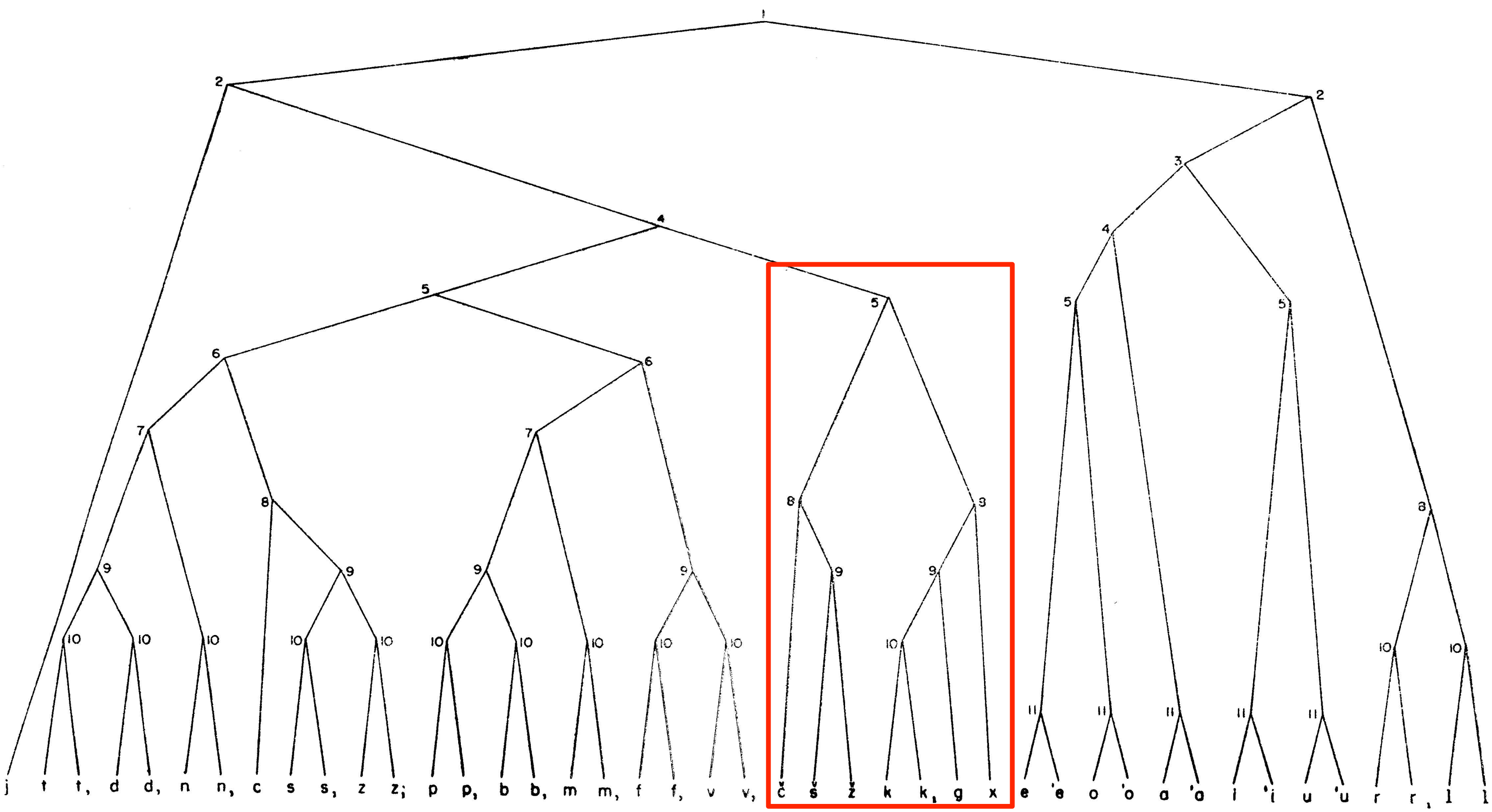
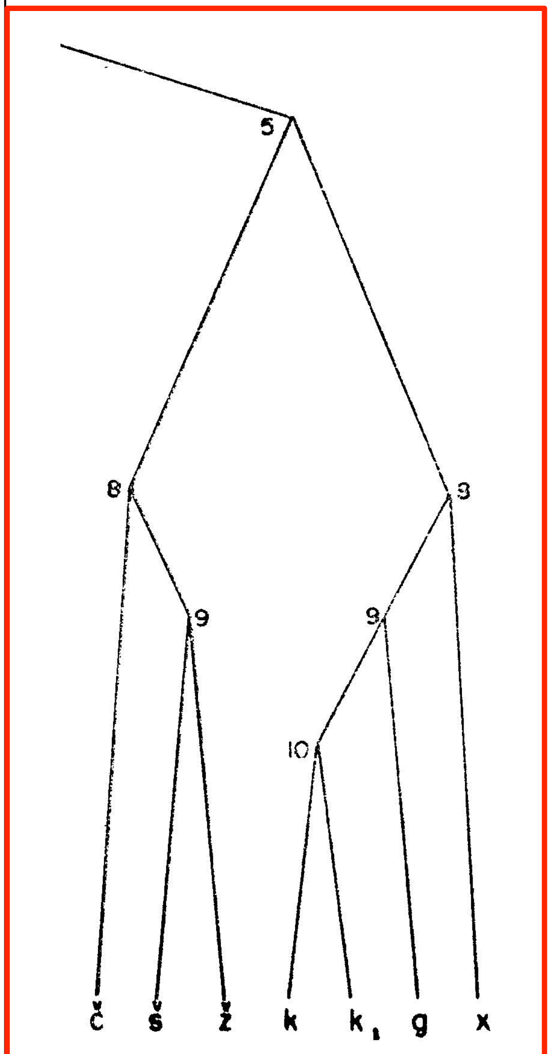
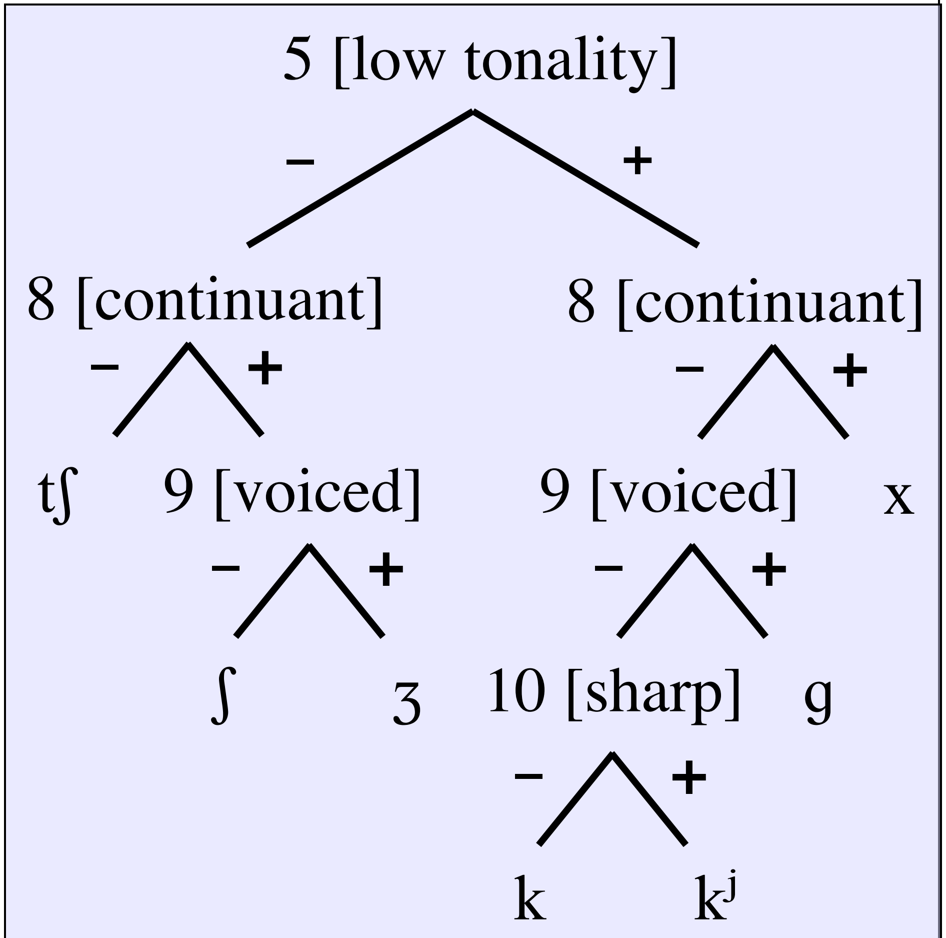


Fig. I-1. Branching diagram representing the morphonemes of Russian. The numbers with which each node is labelled refer to the different features, as follows: 1. vocalic vs. nonvocalic; 2. consonantal vs. nonconsonantal; 3. diffuse vs. nondiffuse; 4. compact vs. noncompact; 5. low tonality vs. high tonality; 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.

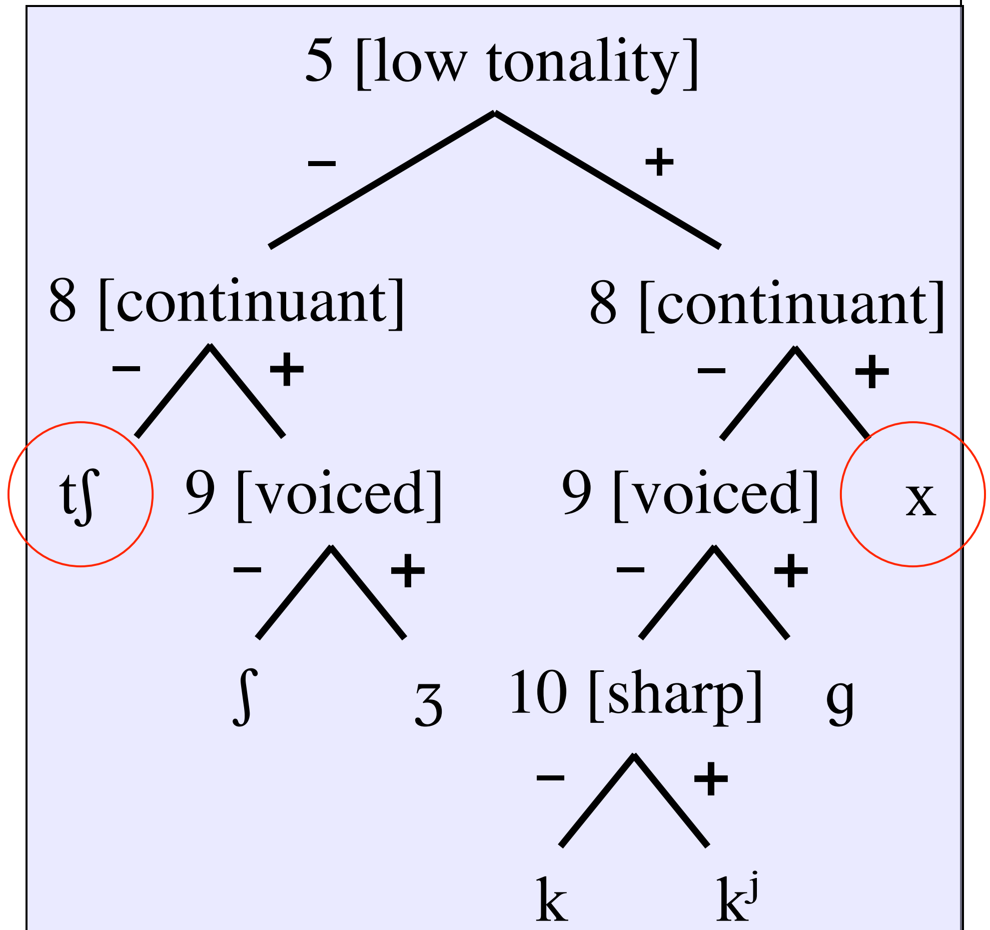
The ordering in another part of the the tree had momentous consequences for the development of phonological theory.





The ordering in another part of the the tree had momentous consequences for the development of phonological theory.

In the ordering shown, /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 is accounted for by the following rules:

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

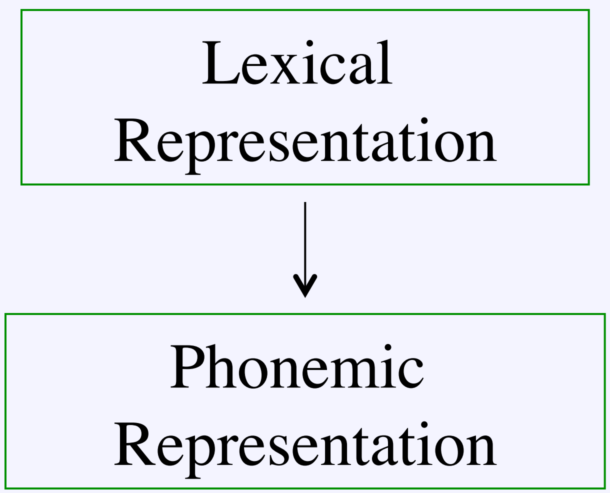
Rule P 3a: If an obstruent cluster is followed [...] by a sonorant, then with regard to voicing the cluster conforms to the last segment.

An example is the derivation of [safxos] 'state farm' from /sovxoz/. The Ø specification for [voiced] of /x/ is immediately filled in, so has no effect on the phonology.

	Underlying		Rule P1b		Rule P3a
	/s o v x o z/	⟶	s o v x o z	⟶	s o f x o z
[+voiced]	+ Ø		+ –		– –

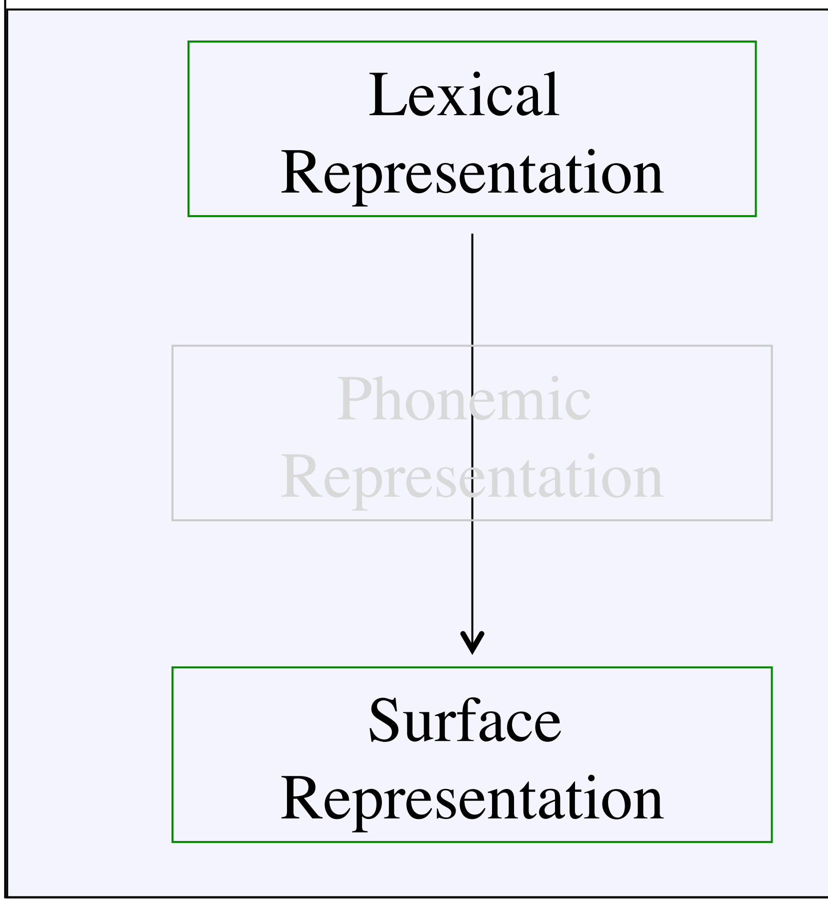
Against the Taxonomic Phoneme

Another factor acting against the Contrastivist Hypothesis in *SPR* involves Chomsky and Halle’s battle against the neo-Bloomfieldian phonemic level (Halle 1959; Chomsky 1964; see Dresher 2005 for discussion).



Against the Taxonomic Phoneme

Chomsky and Halle wanted to recognize only two significant phonological levels:

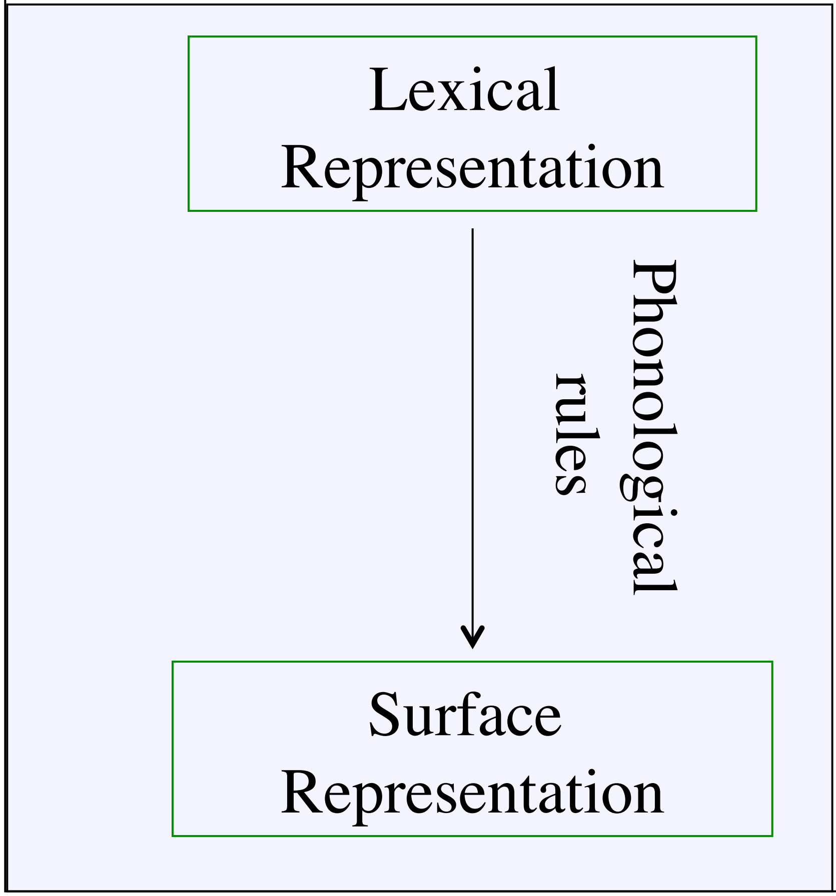


the lexical representation, more or less the older morphophonemic level;

and a phonetic surface level, characterized by the universal set of phonological features.

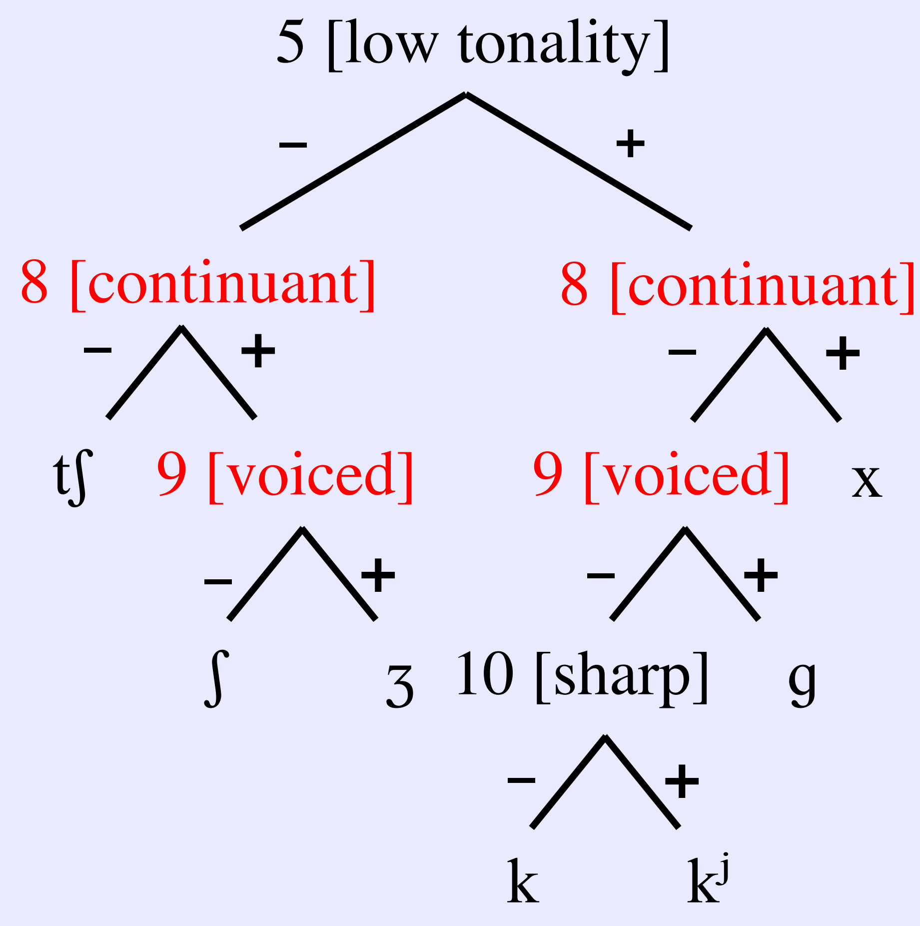
Against the Taxonomic Phoneme

Between underlying and surface levels they envisioned a seamless transition. In this theory, there was no place for making a basic distinction between contrastive and non-contrastive features.

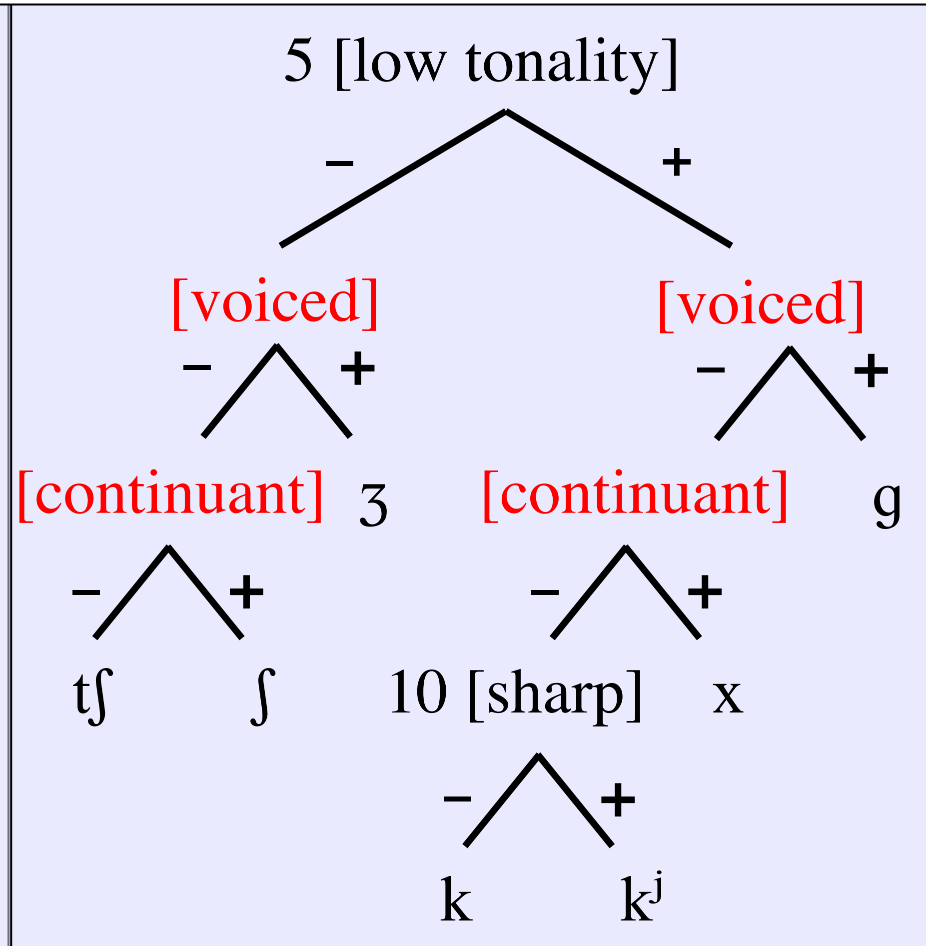


However, a minimal change in the ordering of [continuant] and [voiced] would have put this problem in a different light.

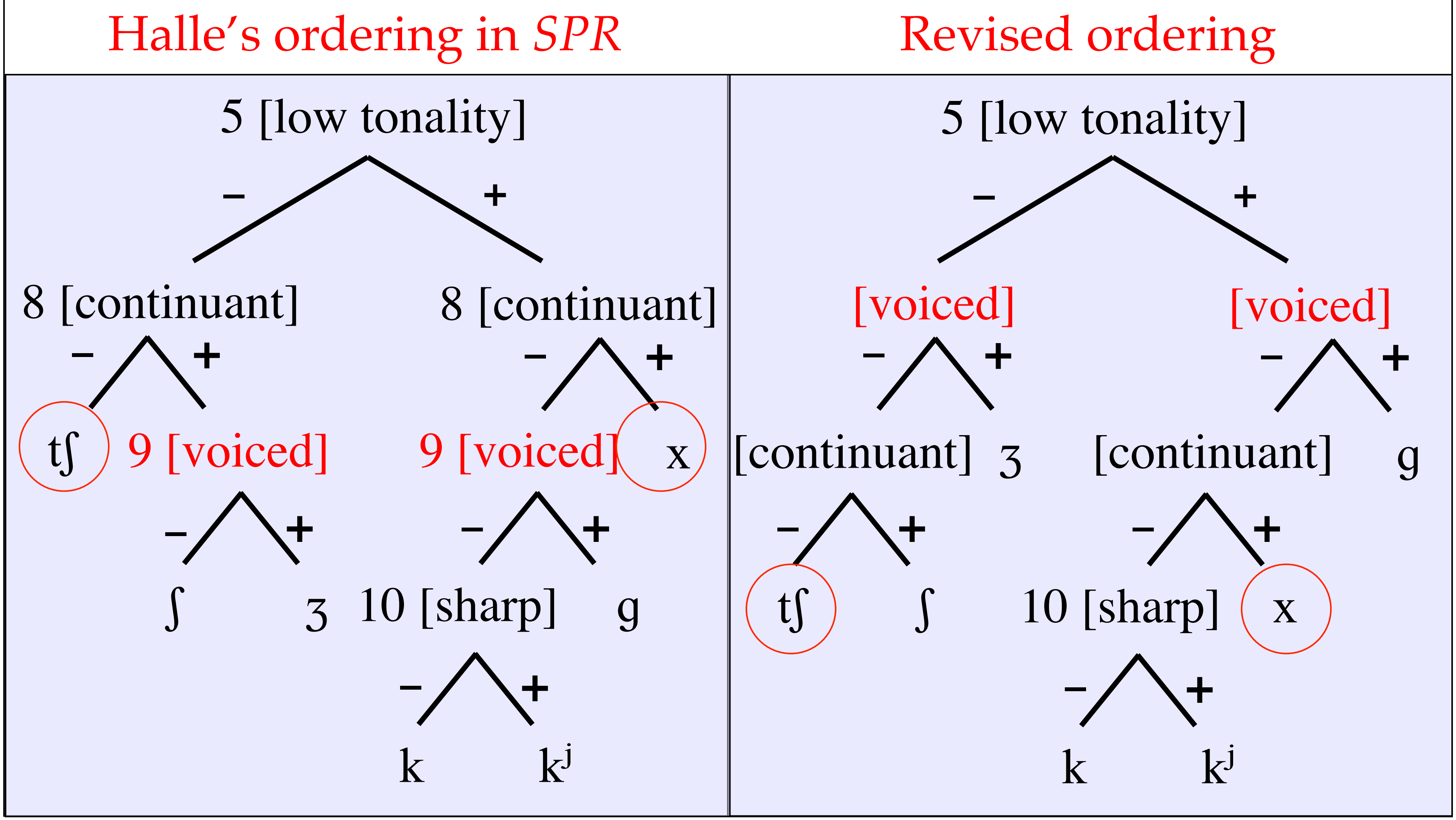
Halle's ordering in *SPR*



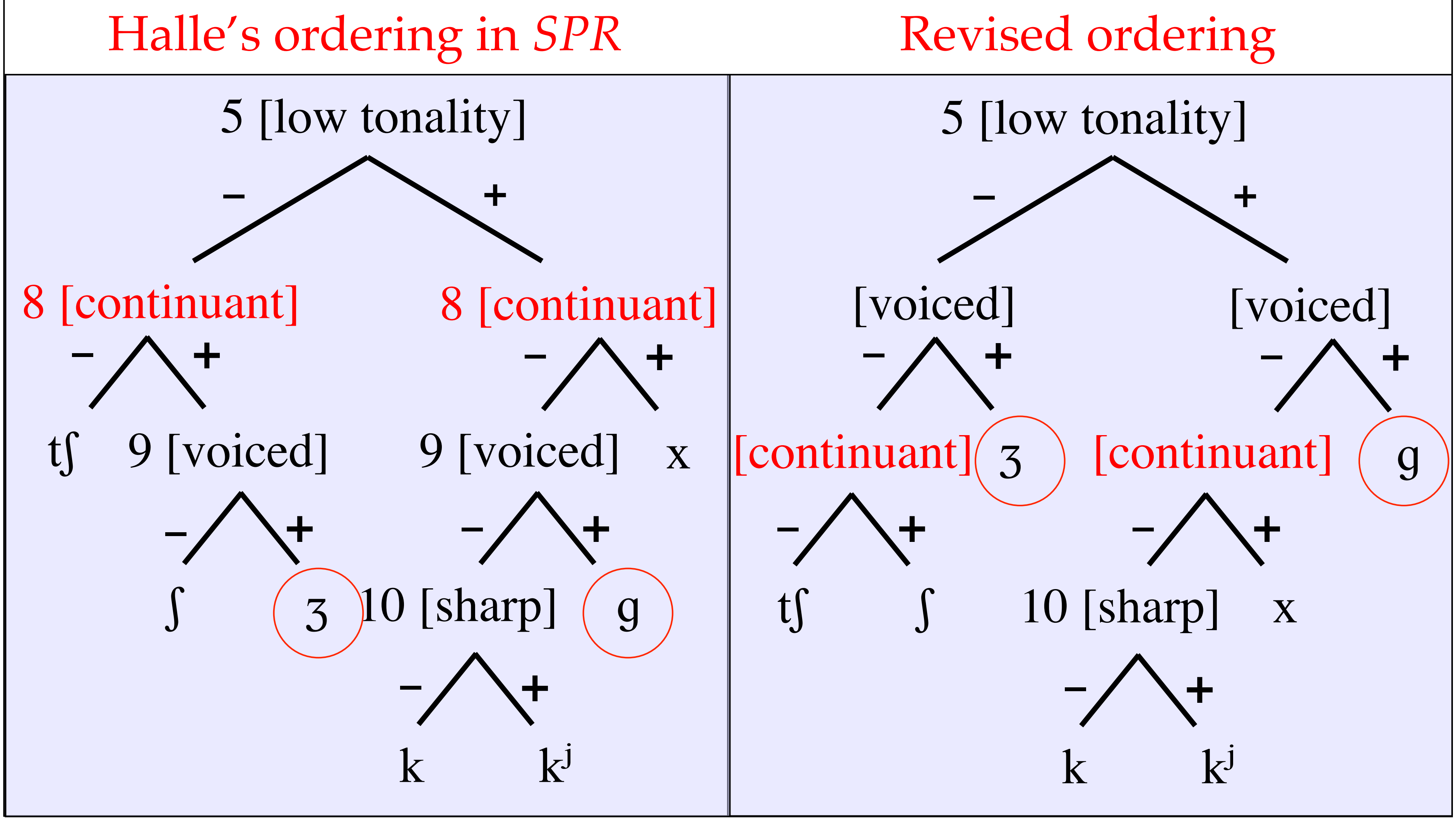
Revised ordering



By ordering [voiced] slightly higher, the 'unpaired' phonemes become contrastively [–voiced], even though they have no voiced counterparts that are minimally different.

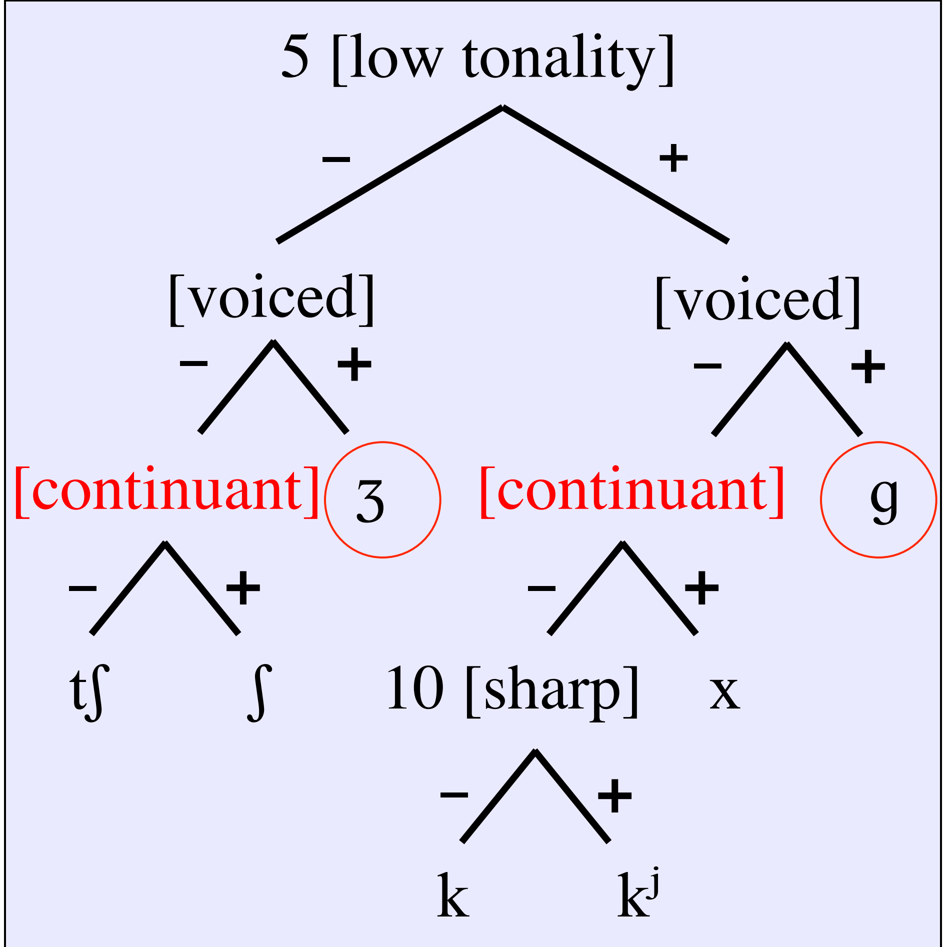


In this case the contrastive hierarchy forces a tradeoff, in that now the voiced consonants /ʒ/ and /g/ are unspecified for [continuant]. Is this a good result? Dresher & Hall (2009) argue that it is.



There is some circumstantial phonetic evidence that it is: In some southern dialects of Russian, /g/ is realized as continuant [ɣ] or [ɦ].

Revised ordering



There is also some (morpho)phonological evidence in the alternations resulting from the First Velar Palatalization; in terms of Halle (1959), the main change is in [low tonality]:

[+low tonality] ⟶ [–low tonality]

/x/ ⟶ [ʃ]

$\begin{bmatrix} \text{–voiced} \\ \text{+continuant} \end{bmatrix}$

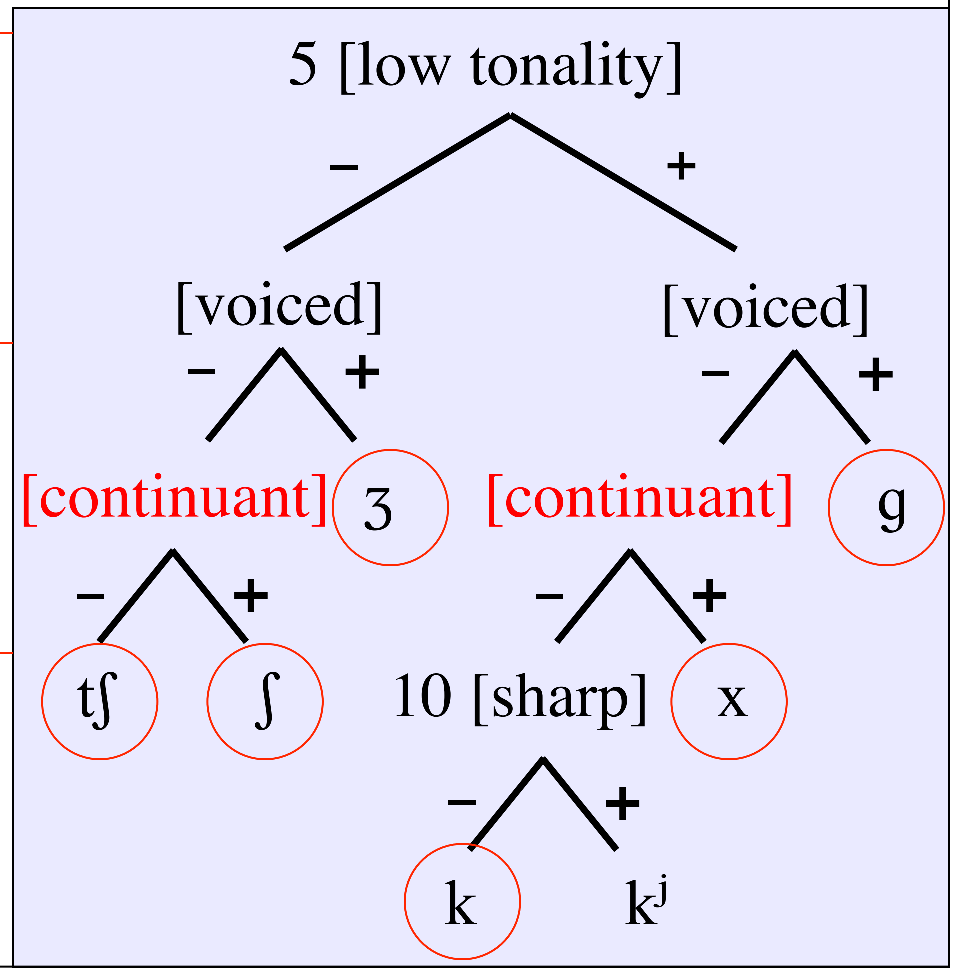
/k/ ⟶ [tʃ]

$\begin{bmatrix} \text{–voiced} \\ \text{–continuant} \end{bmatrix}$

/g/ ⟶ [ʒ]

$\begin{bmatrix} \text{–voiced} \\ \text{0 continuant} \end{bmatrix}$

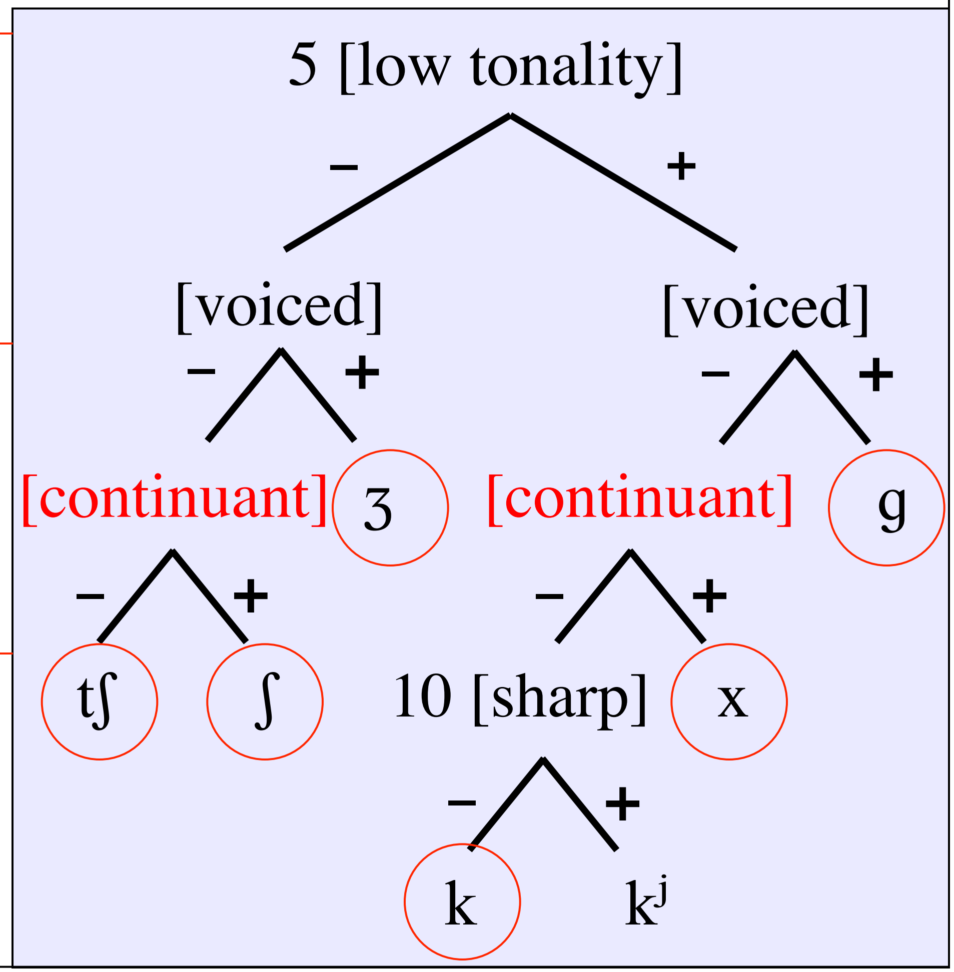
Revised ordering



Whereas continuant /x/ remains continuant [ʃ], and non-continuant /k/ remains non-continuant [tʃ], stop /g/ changes to fricative [ʒ].

[+low tonality]	⟶	[–low tonality]
/x/ [–voiced, +continuant]	⟶	[ʃ]
/k/ [–voiced, –continuant]	⟶	[tʃ]
/g/ [–voiced, 0 continuant]	⟶	[ʒ]

Revised ordering



Some examples are given below (Dresher and Hall 2009); see Radišić (2009) for a similar analysis of such alternations in Serbian.

Adjectives

Positive (m.sg.)	Comparative	Gloss
tʲixij	tʲiʃe	‘quiet(er)’
ʒarkij	ʒarʧe	‘hot(ter)’
dorogoj	doroʒe	‘dear(er)’

Verbs

3rd plural	3rd singular	Gloss
maxut	maʃet	‘wave(s), wag(s)’
pekut	peʧet	‘bake(s)’
strigut	striʒet	‘shear(s)’

Denominal adjectives

Noun	Adjective	Gloss
ʧerepaxa	ʧerepaʃij	‘turtle’ / ‘testudinian’
volk	volʧij	‘wolf’ / ‘lupine’
vrag̊	vraʒij	‘enemy’ / ‘hostile’

Another Argument for Branching Trees in *SPR*

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.

The Distinctness Condition

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.

	A	B	C
Feature 1	–	+	
Feature 2		–	+

The Distinctness Condition

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.

{A} is 'different from' {B}

{A} and {B} are distinguished by F1

	A		B	C
Feature 1	–		+	
Feature 2			–	+

The Distinctness Condition

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.

{B} is 'different from' {C}

{B} and {C} are distinguished by F2

	A	B	C
Feature 1	–	+	
Feature 2		–	+

The Distinctness Condition

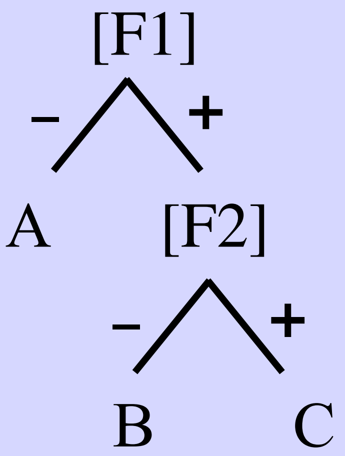
Segment-type {A} will be said to be different from segment-type {B}, if and only if at least one feature which is phonemic in both, has a different value in {A} than in {B}; i.e., plus in the former and minus in the latter, or vice versa.

{A} is not 'different from' {C}

{A} and {C} violate the Distinctness Condition

	A	B	C
Feature 1	–	+	
Feature 2		–	+

The Distinctness Condition



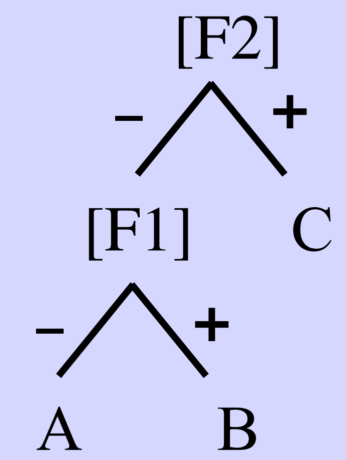
The specifications below violate the Distinctness Condition because no feature hierarchy yields this result.

Ordering [F1] > [F2] yields an extra specification on {C}.

	A	B	C
Feature 1	–	+	+
Feature 2		–	+

The Distinctness Condition

Ordering [F2] > [F1] yields an extra specification on {A}.



	A	B	C
Feature 1	–	+	
Feature 2	–	–	+

The Distinctness Condition

The Distinctness Condition is thus an argument against arriving at contrastive specifications by means of pairwise comparisons.

Pairwise comparisons are a popular, if flawed, method of contrastive specification, as documented in Dresher (2009)

I believe that Halle (1959) is correct in arguing that only a hierarchical approach can guarantee that all segments in an inventory are properly contrasted.

The Demise of the Branching Trees in Generative Phonology

The End of Underspecification

The declining importance of contrastive specification in generative phonology can already be seen in the *The sound pattern of Russian*, 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 Demise of the Contrastive Hierarchy

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.

One notable exception is a 1988 paper in *Phonology* by Charles Cairns.

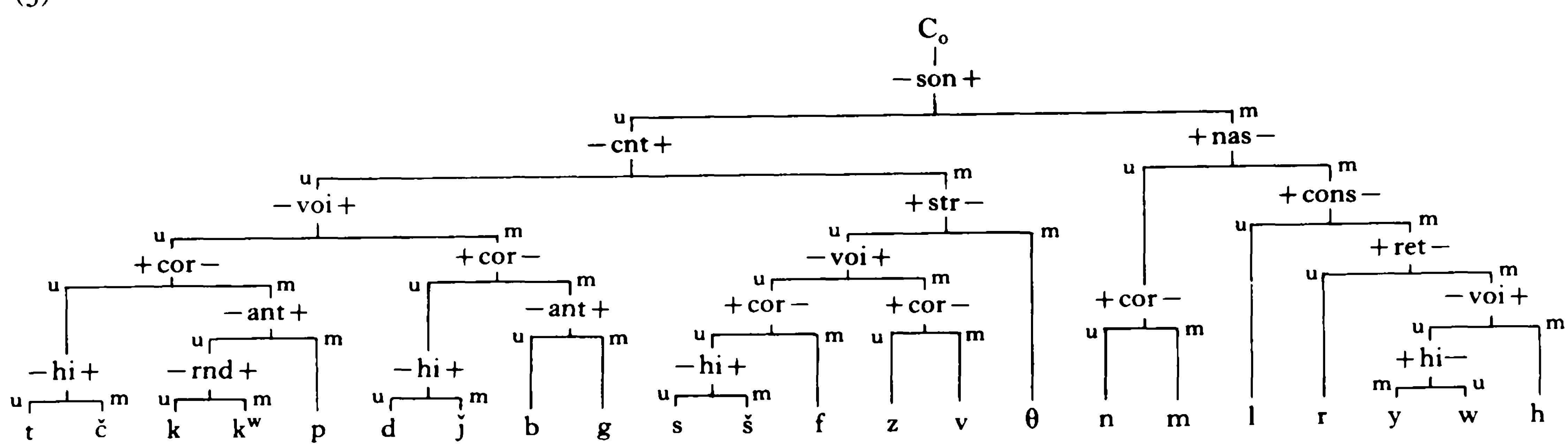
The Contrastive Hierarchy Surfaces!

Cairns makes explicit use of a contrastive hierarchy, which he calls a ‘coding tree’, 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.

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

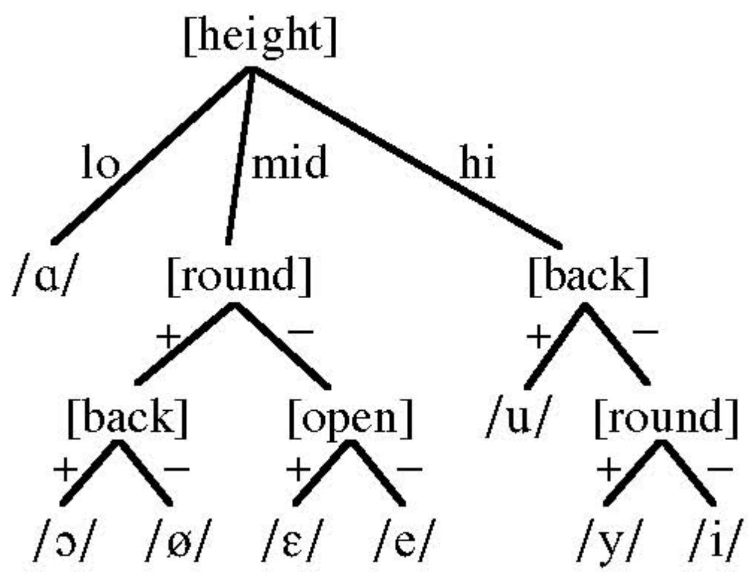
(5)



The Contrastive Hierarchy Surfaces!

The feature hierarchy also makes an appearance in Paul Boersma's 1998 dissertation. Here is a feature tree for Dutch short vowels:

Dutch short vowels



(17.28)

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:

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

Minimality and Activity

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

Active Feature Specification

He proposes a principle of *Active Feature Specification*:

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

"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."

The Contrastivist Hypothesis

This formulation is consistent with what I have called Principle C, and comes close to the Contrastivist Hypothesis. Recall:

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

It follows that only *contrastive* features can be *active* in phonological processes.

But Clements adopts a weaker version of the Contrastivist Hypothesis. He proposes the following conditions for feature specification:

Conditions for feature specification

a. lexical level: distinctiveness

- a feature or feature value is present in the lexicon if and only if it is distinctive

A feature is *distinctive* in a given segment if it is required to distinguish that segment from another.

Up to here this is the same as the Contrastivist Hypothesis.

Conditions for feature specification

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

Conditions for feature specification

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

Conditions for feature specification

Clements (2001: 79): “An interesting question is whether one can maintain the following strong hypothesis:”

> (7) Lexical feature representations are identical to phonological feature representations

“in other words, only lexically distinctive values are phonologically active.”

In other words, the Contrastivist Hypothesis!

☺

Conditions for feature specification

Clements (2001: 79): "An interesting question is whether one can maintain the following strong hypothesis:"

(7) Lexical feature representations are identical to phonological feature representations

"This hypothesis is attractive in that, if true, it would place strong constraints on the nature of feature representation."

"However, we shall see below that some features that are absent in lexical specification are active, and necessarily present, in the phonology, showing that (7) cannot be maintained in its strong form."

☹

Conditions for feature specification

That is, Clements argues on empirical grounds that the Contrastivist Hypothesis is too strong.

This could well 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 vs. Czech /h/, etc.).

Therefore, the Contrastivist Hypothesis fails if there is *no possible ordering* of features available in which only contrastive features are active.

The Accessibility/Robustness Hierarchy

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): "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."

The Accessibility Hierarchy (Clements 2001)

(8) Partial ranked scale of feature accessibility for consonants

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

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.

The Accessibility Hierarchy (Clements 2001)

(8) Partial ranked scale of feature accessibility for consonants

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

For example, [coronal] is at the top of the hierarchy, but Clements asserts that it is usually left unspecified.

Consider his sample 'typical' inventory:

The Accessibility Hierarchy (Clements 2001)

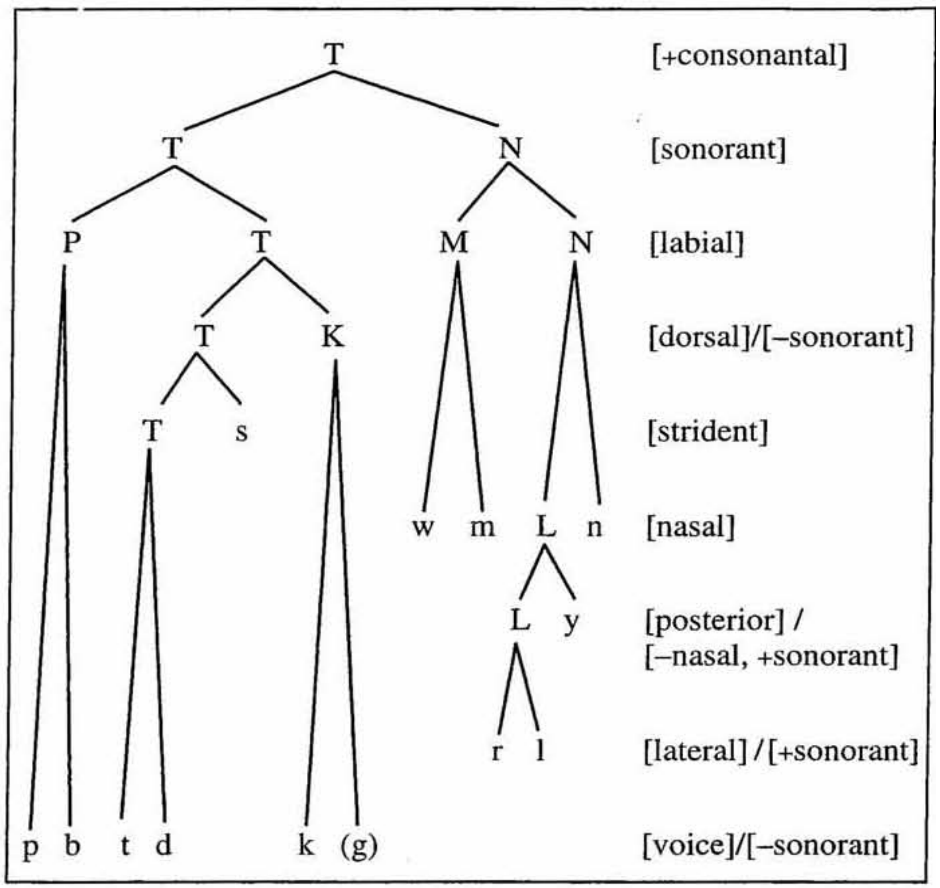


Figure 1. Consonant accessibility, as determined by the scale of feature accessibility (8).

[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.

The Accessibility Hierarchy (Clements 2001)

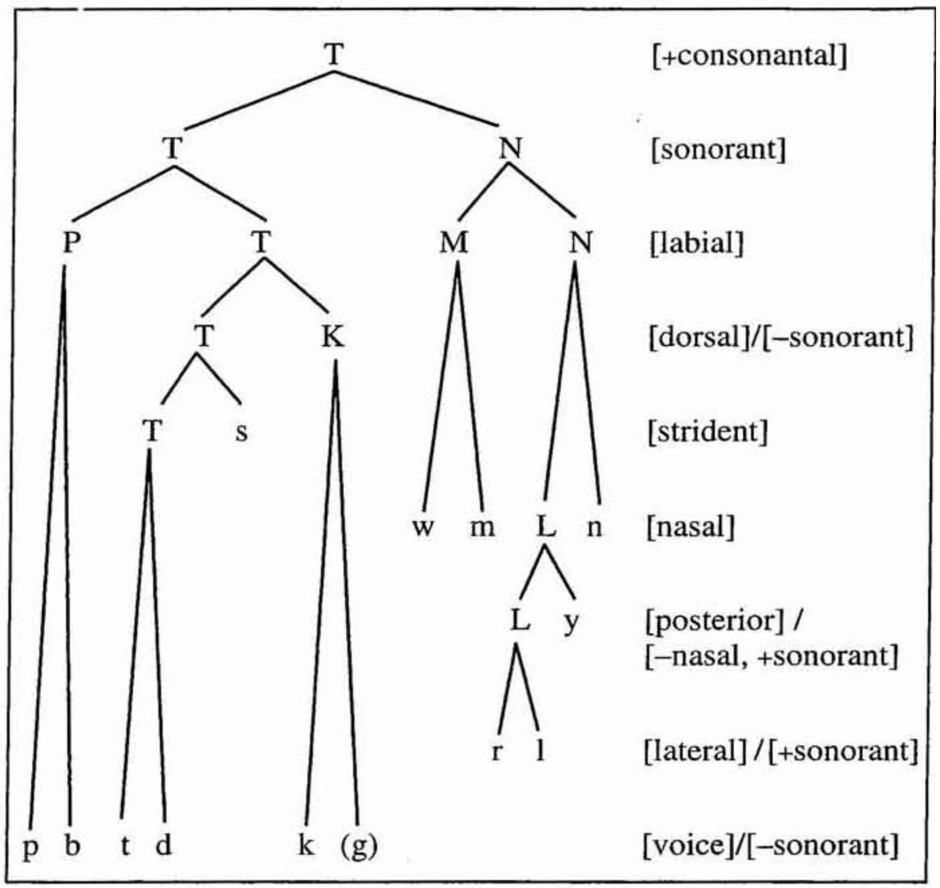


Figure 1. Consonant accessibility, as determined by the scale of feature accessibility (8).

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.

Universality of the Feature Hierarchy

The main difference is that Clements wishes to maintain a *universal* feature hierarchy. Actually, his approach is quite nuanced (Clements 2001: 84–5):

"Is the feature hierarchy in (8), as illustrated in Figure 1, universal across languages? 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."

Universality of the Feature Hierarchy

“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 (8) or one similar to it should be largely respected from one language to another.”

Universality of the Feature Hierarchy

Thus, Clements does allow for some variability in the hierarchy, and he sometimes does make 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, because of his interest in universals of feature economy.

Feature Economy

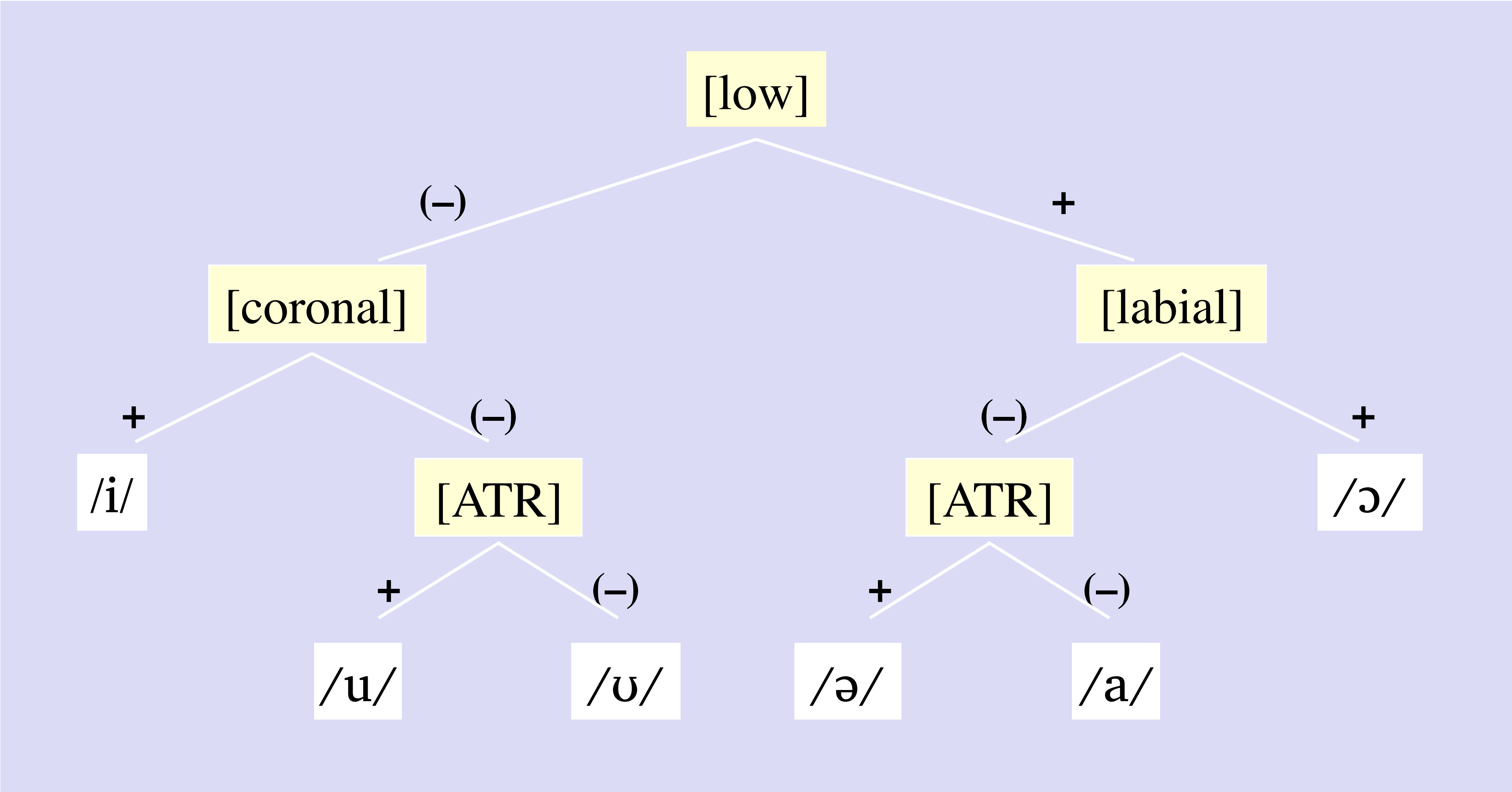
Clements (2003a, b, 2009) has proposed that phonological inventories tend to display Feature Economy.

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.

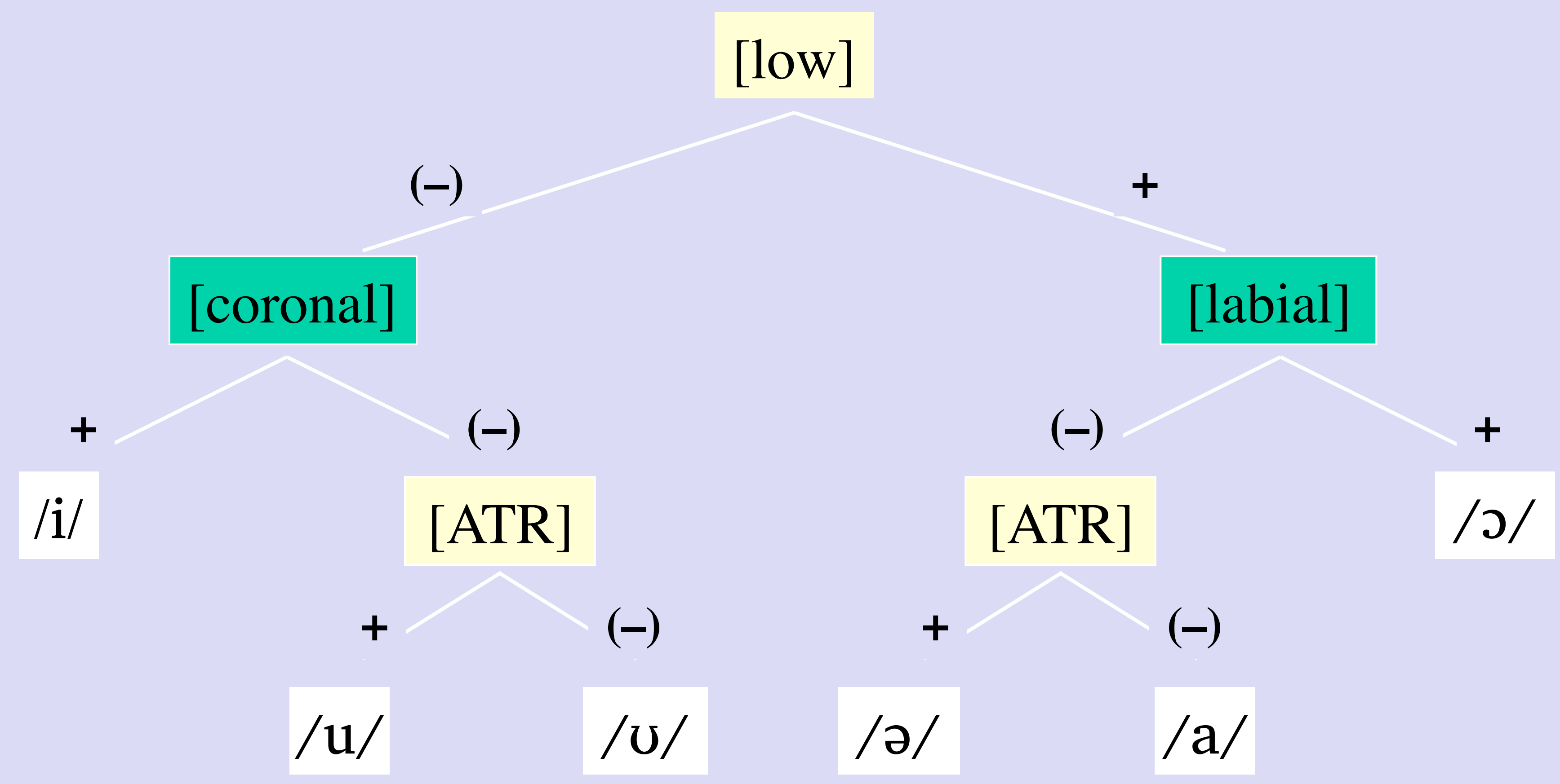
Manchu vowel systems provide an interesting example of this.

Classical Manchu Vowel System (Zhang 1996)



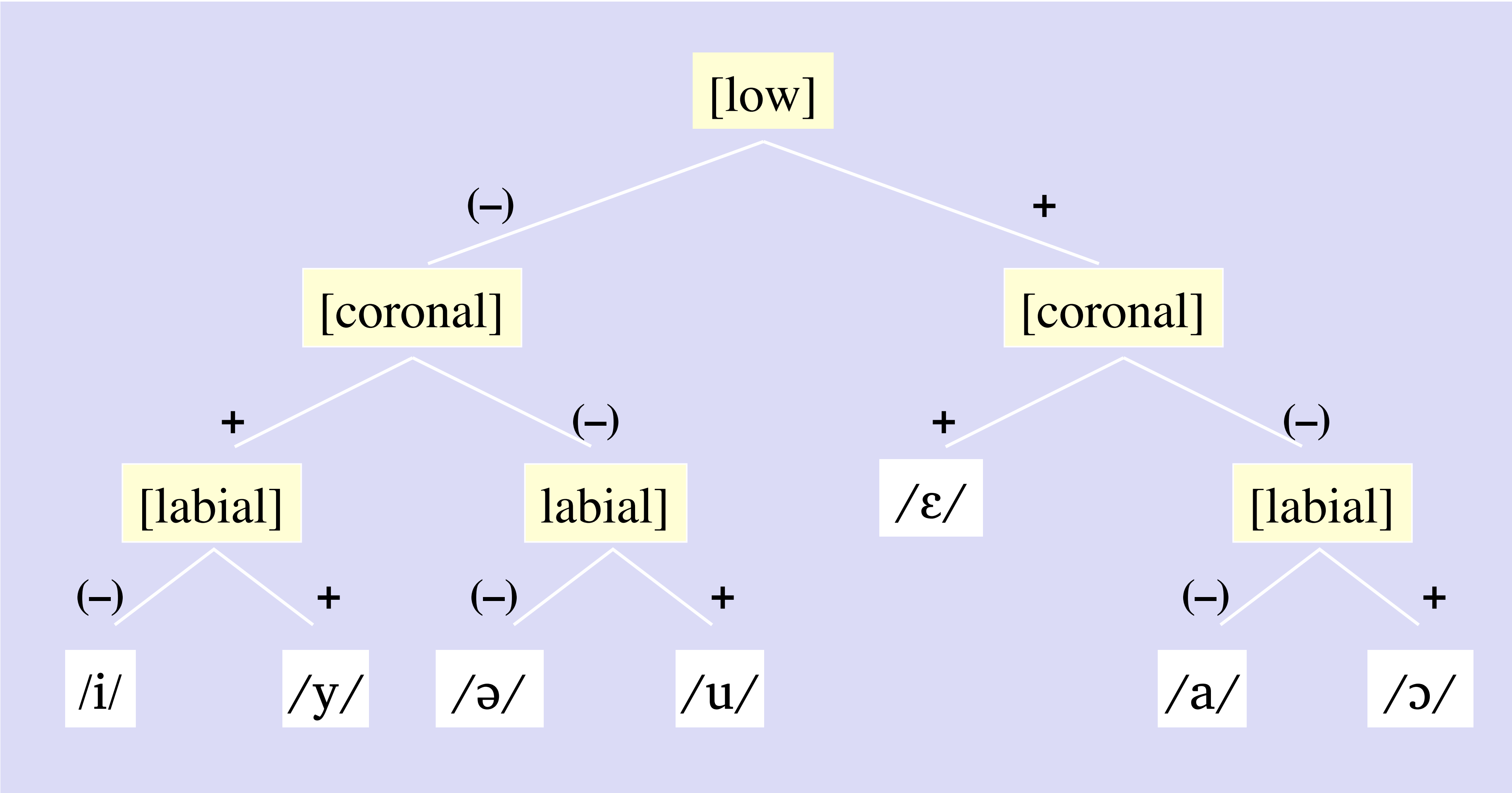
Classical Manchu uses 4 features for 6 vowels. Greater economy could have been achieved for the same inventory by using [labial] rather than [coronal] in the nonlow vowels.

Classical Manchu Vowel System (Zhang 1996)



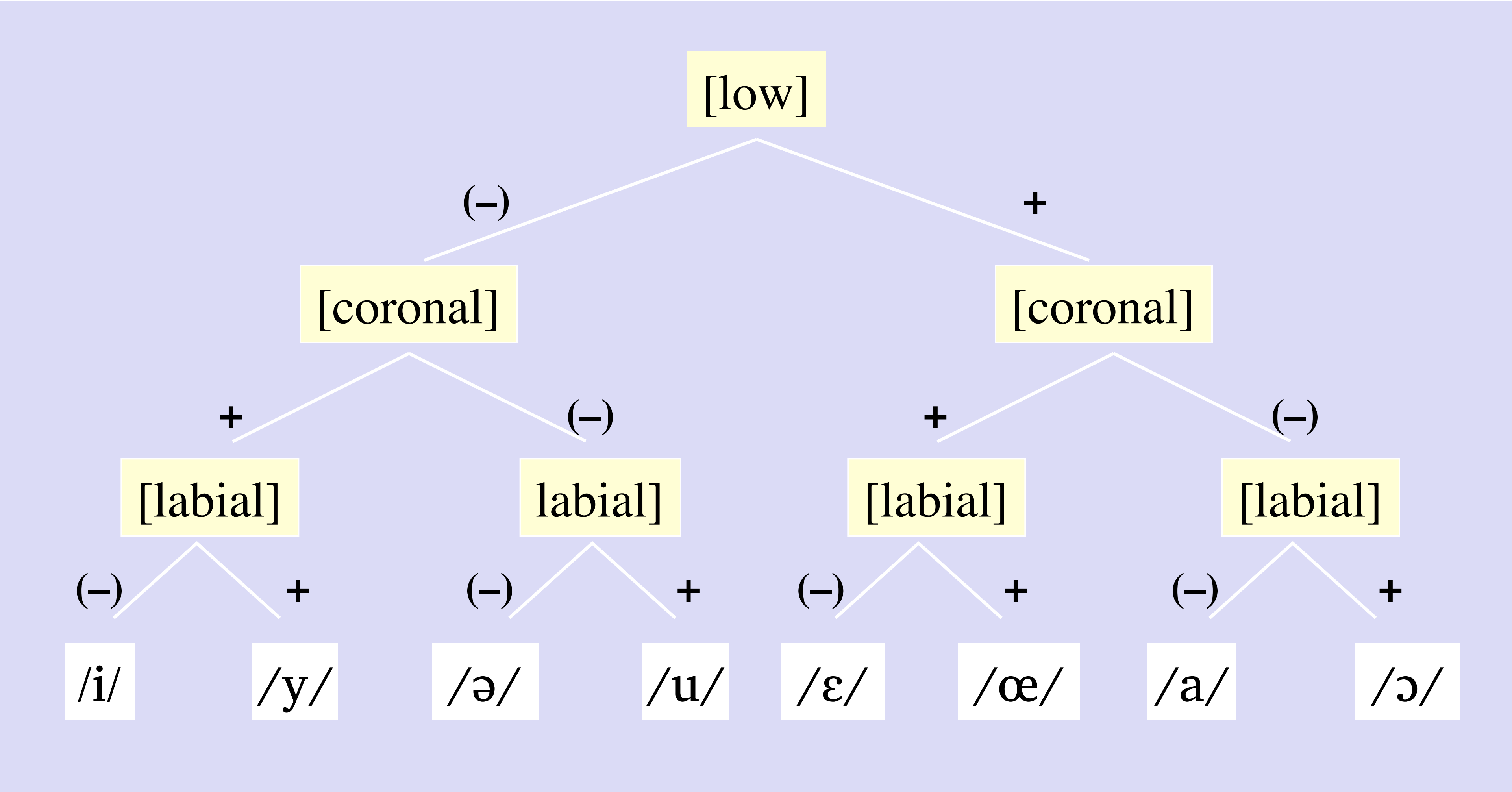
Classical Manchu uses 4 features for 6 vowels. Greater economy could have been achieved for the same inventory by using [labial] rather than [coronal] in the nonlow vowels.

Spoken Manchu Vowel System (Zhang 1996)



Spoken Manchu is a modern descendant of Classical Manchu (or a language closely related to it). It uses fewer features (3) but has more vowel phonemes (7), an increase in Feature Economy.

Xibe Vowel System (Zhang 1996)



Xibe is another modern Manchu dialect. It has a maximally economical (and symmetric) feature system, with 8 phonemes using 3 features.

Feature Economy

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.

The Robustness Hierarchy (Clements 2009)

The Robustness Scale is a somewhat revised version of the Accessibility Scale.

Rather than a strict ranking, features are placed in 5 groups of decreasing likelihood of occurring.

There are also some changes in the ordering.

Robustness scale: consonants

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

Among other changes, [continuant] and [posterior] have been promoted, and [strident] and [lateral] have been demoted.

Partial accessibility scale for consonants		Robustness scale: consonants	
	feature:		*feature:*
a.	[coronal]	a.	[±sonorant]
b.	[sonorant]		[labial]
c.	[labial]		[coronal]
d.	[dorsal]		[dorsal]
e.	[strident]	b.	[±continuant]
f.	[nasal]		[±posterior]
g.	[posterior]	c.	[±voiced]
h.	[lateral]		[±nasal]
i.	[voice]	d.	[glottal]
		e.	others

Feature Economy

In order to maintain the proposed universal hierarchy, Clements (2009) is inclined to interpret the contrasts in inventories in accordance with the Robustness hierarchy, favouring it over other possible analyses.

For example, he again considers a typical consonant inventory; capital letters indicate consonant types:

P	T		K	
	S			
M	N			
W	L~R	J		H ~ ʔ

Feature Economy

For example, he considers that /T/~ /S/ are distinguished by [continuant], not [strident]; similarly, the /L/ ~ /J/contrast could be based on [continuant] or [posterior], but not [lateral].

These may be the correct analyses in many, possibly most, maybe even all, inventories.

The crucial cases arise when phonological patterning diverges from the proposed universal ordering.

P	T		K	
	S			
M	N			
W	L~R	J		H ~ ʔ

Weighting Rationales for Feature Hierarchies

To sum up, Clements does appeal to Principle C: “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.”

Principle C

The purpose of a feature hierarchy is to identify the contrastive features that are relevant to the phonological computation.

Weighting Rationales for Feature Hierarchies

But in the end he gives preference to Principle B, which requires a universal feature hierarchy, to the extent possible:

Principle B

The purpose of a feature hierarchy is to express universal tendencies in the nature of phonological inventories.

Weighting Rationales for Feature Hierarchies

Principle C

The purpose of a feature hierarchy is to identify the contrastive features that are relevant to the phonological computation.

Principle B

The purpose of a feature hierarchy is to express universal tendencies in the nature of phonological inventories.

Loanword Adaptation as an Example of Activity

Recall that Jakobson and 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.

Contrastive Hierarchy for Hawaiian

Hawaiian

p		k	ʔ
			h
m	n		
w	l		

Clements proposes the following feature ordering for Hawaiian:

Contrastive Hierarchy for Hawaiian

Hawaiian

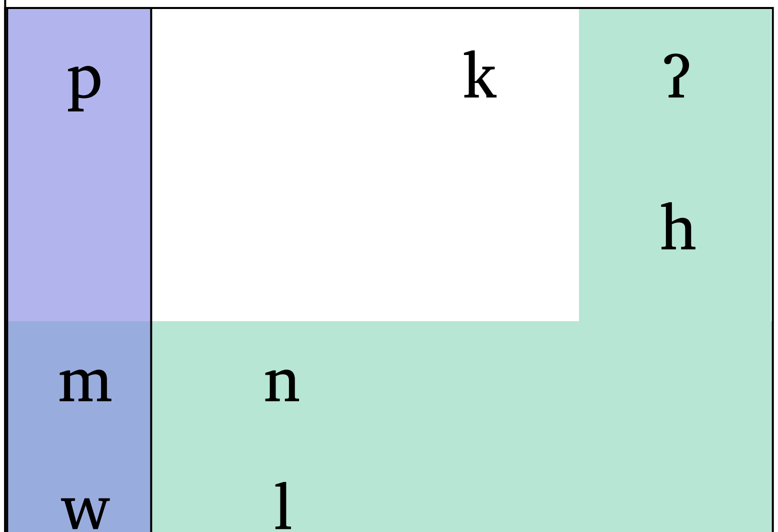
p		k	ʔ
			h
m	n		
w	l		

Clements proposes the following feature ordering for Hawaiian:

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

Contrastive Hierarchy for Hawaiian

Hawaiian

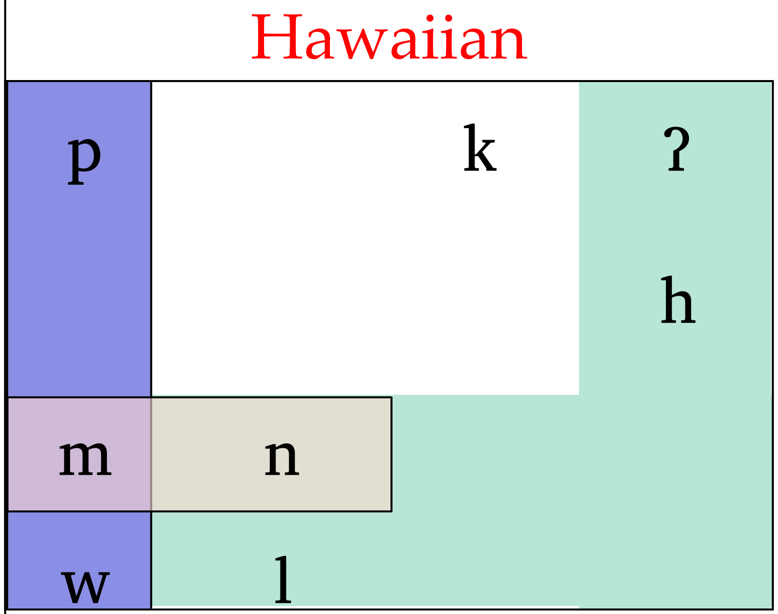


Clements proposes the following feature ordering for Hawaiian:

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

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

Contrastive Hierarchy for Hawaiian



Clements proposes the following feature ordering for Hawaiian:

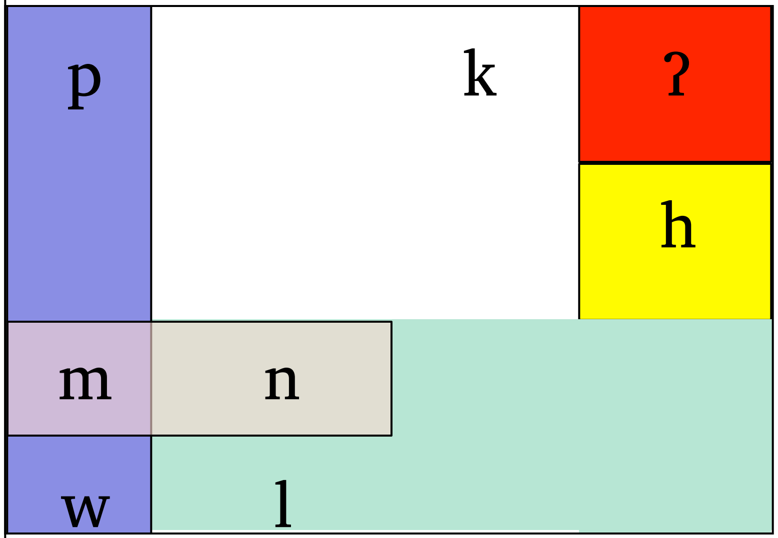
First, [sonorant] distinguishes /m, n, w, l, ʔ, h/ from /p, k/.

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

Next, [nasal] makes /m, n/ unique.

Contrastive Hierarchy for Hawaiian

Hawaiian



Clements proposes the following feature ordering for Hawaiian:

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

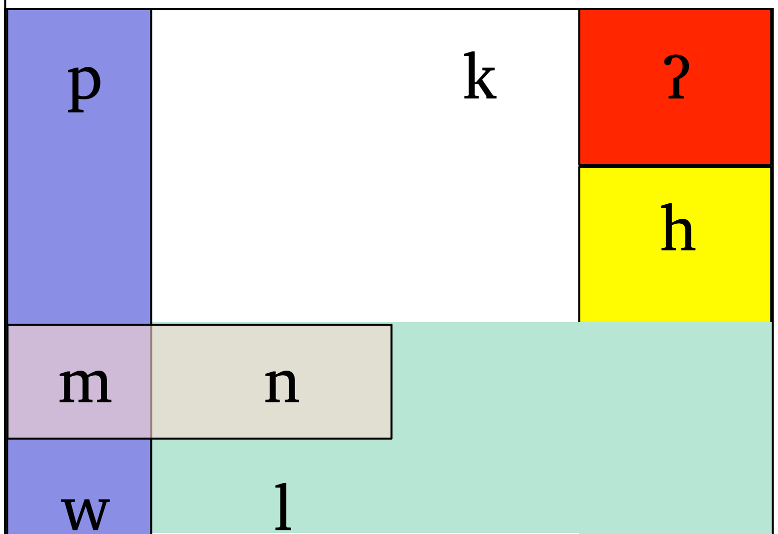
Next, [labial] splits off /p, m, w/ from the rest.

Next, [nasal] makes /m, n/ unique.

Then, [spread]applies to /h/ and [constricted] to /ʔ/.

Contrastive Hierarchy for Hawaiian

Hawaiian



Clements proposes the following feature ordering for Hawaiian:

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

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

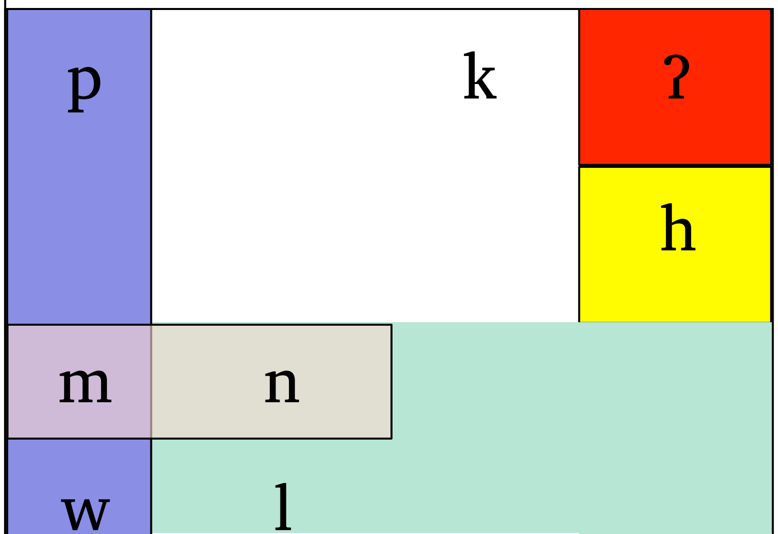
Next, [nasal] makes /m, n/ unique.

Then, [spread]applies to /h/ and [constricted] to /ʔ/.

This leaves /k/ as the default consonant that is none of the above.

Contrastive Hierarchy for Hawaiian

Hawaiian



Clements argues that productive adaptation patterns of English loanwords into Hawaiian support this analysis.

Clements proposes the following feature ordering for Hawaiian:

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

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

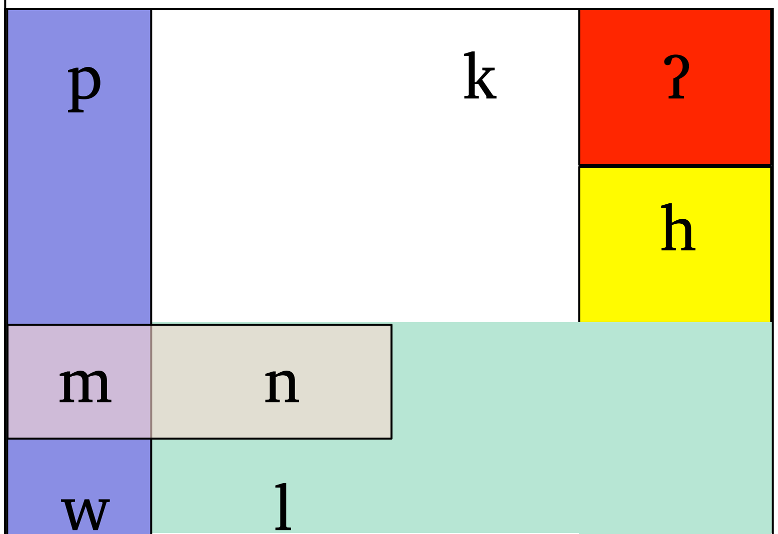
Next, [nasal] makes /m, n/ unique.

Then, [spread]applies to /h/ and [constricted] to /ʔ/.

This leaves /k/ as the default consonant that is none of the above.

Contrastive Hierarchy for Hawaiian

Hawaiian



For example, coronal obstruents, [g] > /k/

They are not [sonorant], [labial], [nasal], [spread] [constricted], hence /k/

[s] --> /k/

lettuce--> /lekuke/

soap--> /kope/

[z] --> /k/

dozen --> /kaakini/

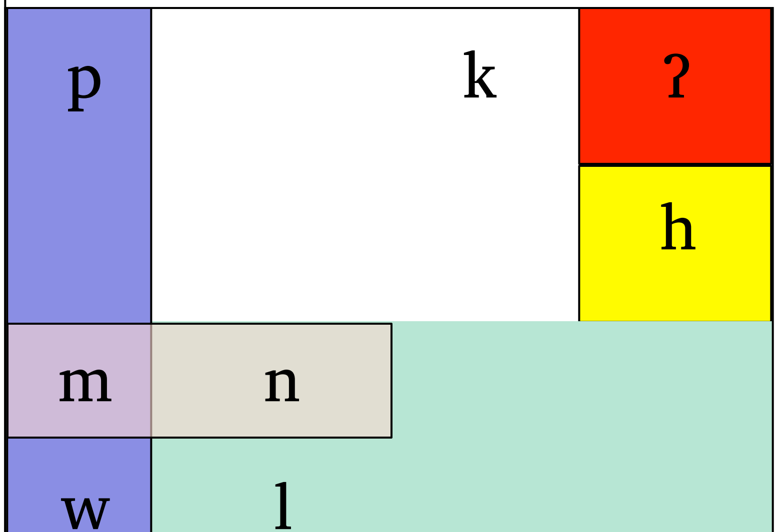
[ʃ] --> /k/

brush --> /palaki/

machine --> /mikini/

Contrastive Hierarchy for Hawaiian

Hawaiian



[b], [f] > /p/

They are not [sonorant], but they are [labial], hence /p/.

Clements proposes the following feature ordering for Hawaiian:

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

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

Next, [nasal] makes /m, n/ unique.

Then, [spread]applies to /h/ and [constricted] to /ʔ/.

This leaves /k/ as the default consonant that is none of the above.

Extending the Analysis

Hawaiian

p		k	ʔ
			h
m	n		
w	l		

NZ Māori

p	t	k	
f			h
m	n	ŋ	
w	r		

Herd (2005) builds on Clements's analysis, and looks at patterns of loanword adaptation in related languages.

In New Zealand Māori, with a slightly larger consonant inventory, coronal obstruents are adapted as /h/, not as /k/, and not as /t/.

Hawaiian	NZ Māori
[s] → /k/	[s] → /h/
lettuce → /lekuke/	glass → /karaahe/
soap → /kope/	sardine → /haarini/
[z] → /k/	[z] → /h/
dozen → /kaakini/	weasel → /wiihara/
	rose → /roohi/
[ʃ] → /k/	[ʃ] → /h/
brush → /palaki/	brush → /paraihe/
machine → /mikini/	sheep → /hipi/

Inventory of NZ Māori

Hawaiian

p		k	ʔ
			h
m	n		
w	l		

NZ Māori

p	t	k	
f			h
m	n	ŋ	
w	r		

This is somewhat surprising, since the analysis we used for Hawaiian will not give this result.

Inventory of NZ Māori

NZ Māori

p	t	k	
f			h
m	n	ŋ	
w	r		

In particular, if we follow the order [sonorant] > [labial] > [dorsal] > [nasal] > [spread], we end up with /t/ as the default consonant that ought to be used for English coronal obstruents.

Different Contrasts in the Inventories

Hawaiian

p		k	ʔ
			h
m	n		
w	l		

NZ Māori

p	t	k	
f			h
m	n	N	
w	r		

Herd (2005) proposes that the contrastive status of /h/ is different in these languages. Hawaiian has both /h/ and /ʔ/. Following Avery and Idsardi (2001), the existence of this contrast activates a laryngeal dimension they call *Glottal Width*.

Glottal Width has two values, [constricted] for /ʔ/, and [spread] for /h/. This is as in Clements's analysis.

Different Contrasts in the Inventories

Hawaiian

p		k	ʔ
			h
m	n		
w	l		

NZ Māori

p	t	k	
f			h
m	n	N	
w	r		

But NZ Māori has no /ʔ/, so there is no contrast within Glottal Width; therefore, [spread] is not accessible in this system.

A further change is required to make this analysis work: we must assume that /h/ is [–sonorant], contrary to Clements's analysis.

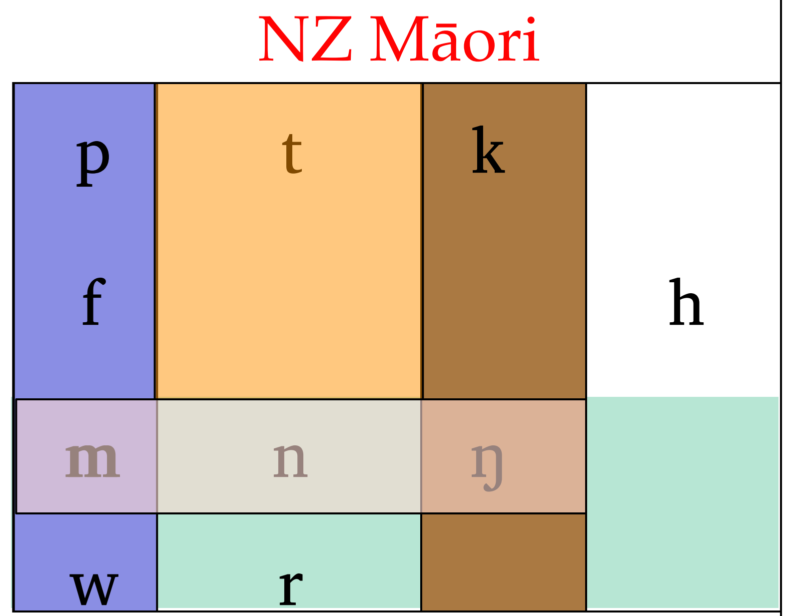
Inventory of NZ Māori

NZ Māori

p	t	k	
f			h
m	n	ŋ	
w	r		

Following the same order as before but with these changes, we have [sonorant] > [labial] > [dorsal] > [nasal]. But now [spread] does not come so high in the order.

Inventory of NZ Māori



The next feature to be assigned is [dental] for /t/, chosen because English interdental fricatives are adapted as /t/. This leaves /h/ as the default consonant that ought to be used for other English coronal obstruents.

Variation in the Feature Hierarchy

We conclude that the same logic that leads Clements (2001) to posit one feature hierarchy for Hawaiian leads us to a different hierarchy for NZ Māori.

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

Conclusion

Conclusion

Next to the many other important contributions that 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 mind.

I believe, however, that feature hierarchies have not yet revealed their full potential to illuminate the synchronic and diachronic patterning of phonological systems.

Their groundbreaking studies clear a path to the further exploration of this aspect of phonological theory.

Conclusion

I will conclude with the words of Jakobson, Fant and Halle (1952: 9):

> The dichotomous scale is the pivotal principle of the linguistic structure. The code imposes it upon the sound.

Thank you!

I am grateful to members of the project on
Markedness and the Contrastive Hierarchy in Phonology at
the University of Toronto (Dresher and Rice 2007):

http://homes.chass.utoronto.ca/~contrast/

This research was supported in part by grants
410-2003-0913 and 410-08-2645 from the Social
Sciences and Humanities Research Council of Canada.

References

Avery, Peter and William J. Idsardi. 2001. Laryngeal dimensions, completion and enhancement. In T. Alan Hall (ed.), *Distinctive feature theory*, 41–70. Berlin: Mouton de Gruyter.

Boersma, Paul. 1998. *Functional phonology: Formalizing the interactions between articulatory and perceptual drives*. The Hague: Holland Academic Graphics.

Cairns, Charles E. 1988. Phonotactics, markedness and lexical representation. *Phonology* 5: 209–236.

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

Chomsky, Noam. 1964. Current issues in linguistic theory. In Jerry A. Fodor and Jerrold J. Katz (eds.), *The structure of language*, 50–118. Englewood Cliffs, NJ: Prentice-Hall.

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

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

Clements, G. N. 2003a. Feature economy as a phonological universal. In María-Josep Solé, Daniel Recasens and Joaquín Romero (eds.), *Proceedings of the 15th International Congress of Phonetic Sciences, Barcelona, 3–9 August 2003*, 371–374. Rundle Mall, Australia: Causal Productions (CD-ROM); Barcelona: Futurgraphic (print).

Clements, G. N. 2003b. 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,* 19–68. Cambridge, Mass.: MIT Press.

Dresher, B. Elan. 1998. On contrast and redundancy. Paper presented at the annual meeting of the Canadian Linguistic Association, May, 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*, 239–57. Amsterdam: John Benjamins.

Dresher, B. Elan. 2005. Chomsky and Halle's revolution in phonology. In James McGilvray (ed.), *The Cambridge companion to Chomsky*, 102–22. Cambridge: Cambridge University Press.

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

Dresher, B. Elan and Daniel Currie Hall. 2009. Contrast in the Twentieth Century and Beyond. Presented at the 17th Manchester Phonology Meeting, University of Manchester, May 2009.

Dresher, B. Elan and Keren Rice. 2007. Markedness and the contrastive hierarchy in phonology. http://homes..chass.utoronto.ca/~contrast/.

Groot, A. W. de. 1931. Phonologie und Phonetik als Funktionswissenschaften. *Travaux du Cercle Linguistique de Prague* 4: 116–147.

Hall, Daniel Currie. 2007. The role and representation of contrast in phonological theory. Doctoral dissertation, University of Toronto.

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

Herd, Jonathon. 2005. Loanword adaptation and the evaluation of similarity. *Toronto Working Papers in Linguistics (Special issue on similarity in phonology* 24: 65–116.

Jakobson, Roman. 1962 [1931]. Phonemic notes on Standard Slovak. In Roman Jakobson, *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 and Morris Halle. 1956. *Fundamentals of Language*. The Hague: Mouton.

Jakobson, Roman, C. Gunnar M. Fant and 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 and John Lotz. 1949. Notes on the French phonemic pattern. *Word* 5: 151–8.

Kaye, Jonathan, Jean Lowenstamm and Jean-Roger Vergnaud. 1985. The internal structure of phonological elements: a theory of charm and government. *Phonology Yearbook* 2: 305–28.

Martinet, André. 1955. *Économie des changements phonétiques*. Bern: A. Francke.

Martinet, André. 1968. Phonetics and linguistic evolution. In *Manual of phonetics*, revised and extended edition, ed. by Bertil Malmberg, 464–87. Amsterdam: North-Holland. Reprinted from the first edition edited by Louise Kaiser, 1957, 252–73.

Radišić, Milica. 2009. The double nature of the velar /g/ in Serbian. *Toronto Working Papers in Linguistics* 30: 91–103.

Stanley, Richard. 1967. Redundancy rules in phonology. *Language* 43: 393–436.

Trubetzkoy, N. S. 1939. *Grundzüge der Phonologie*. Göttingen: Vandenhoek & Ruprecht.

Trubetzkoy, N. S. 1969. *Principles of Phonology*. Translation of Trubetzkoy (1939) by Christiane A. M. Baltaxe. Berkeley: University of California Press.

Zhang, Xi. 1996. Vowel systems of the Manchu-Tungus languages of China. Doctoral dissertation, University of Toronto.