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The Intrinsic Structure of Speech Sounds

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In this paper I shall be concerned with the intrinsic structure of speech sounds. That speech sounds have such a structure is now quite generally accepted, and the evidence for this proposition comes from two rather different domains which I call here phonetic and grammatical. Phonetically speech sounds are acoustic signals produced by a special gymnastics of the different articulators that make up the human vocal tract and they are traditionally grouped into sets defined by their articulatory and acoustic attributes. Thus, the consonants in the set [p b m f v] share the fact of being produced with active involvement of the lip or labial articulator, and it is this phonetic fact that distinguishes them from the set [t d n s z] which is made up of sounds produced with active involvement of the tongue blade or coronal articulator. It is therefore common practice now to refer to the former set as the labial consonants and to the latter as the coronal consonants.

In addition to their phonetic differences these two sets of sounds also differ with respect to their grammatical role. For example, as shown in (1a) in English the vocalic nucleus [aw] occurs freely before the coronal consonants [t d n s z], but it is excluded before the labial set, and words such as those in (1b) are not well-formed in English.

(1) a. out loud town house rouse

b. *[awp] *[lawb] *[tawm] *[hawf] *[rawv]

The study of grammatical regularities of all kinds has established that phonetically motivated sets of speech sounds figure in grammatical processes almost to the total exclusion of other possible groupings. As a consequence in the grammatical processes of different languages we find goupings such as the two just illustrated as well as some others given in (2a), but sets such as those in (2b) are hardly ever found.

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1. In preparing this paper I have profited from the help and advice of A. Calabrese, F. Dell, M. Hegarty, J. McCarthy and L. Trigo as well as of audiences at the Ohio State University and at MIT, where versions of the paper were presented. I am grateful to them all, even if I have not seen my way clear to incorporating all of their suggestions. Remaining shortcomings are, of course, my responsibility alone.

(2) a. p b m f v   i e ae   p t k b d g

b. k b n i f   e p d   i e ae p t k

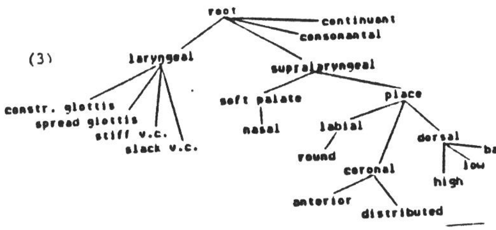
What is important to us about the two sets of sounds is that the sets that exist share certain obvious phonetic properties such as being produced with a particular articulator -- like [p b m f v] -- or with a specific articulatory gesture -- like [p t k b d g] -- or with both -- like [i e ae], whereas sets whose members lack such phonetic similarities are never encountered.

Until relatively recently it was assumed almost universally that the complexes of features that compose the different sounds are just lists without further intrinsic structure. This conception was challenged by a number of workers most notably and effectively by Clements. In his important paper on feature geometry in the 1985 volume of the Phonology Yearbook Clements argued that the features in the list must be organized into groups of various kinds. The evidence that Clements used in support of his argument was grammatical, it derived mainly from the behavior of phonemes in different assimilatory processes. Clements was quite explicit about this: "If we find that certain sets of features consistently behave as a unit with respect to certain types of rules of assimilation or resequencing, we have good reason to suppose that they constitute a unit in phonological representation, independently of the operation of the rules themselves. There is a useful analogy here to syntax: many of the most enduring results of syntactic analysis have been made possible by the recognition that word-groups functioning as single units with respect to syntactic rules form hierarchical constituents in phrase structure analysis." (p.226)

Clements focused particular attention on instances where assimilation affected more than one but less than the entire complement of features of a speech sound, and he observed that such partial assimilations do not involve just any arbitrary subset of features, but rather only a very small number of such subsets. For example, as Clements noted, voicing and aspiration often assimilate together, but voicing and lip rounding never do.

To account for such observations Clements proposed that the features composing the different speech sounds are grouped into hierarchies of subsets of the sort illustrated in (3) and that phonological rules and regularities can make reference only to such feature subsets or to single features.

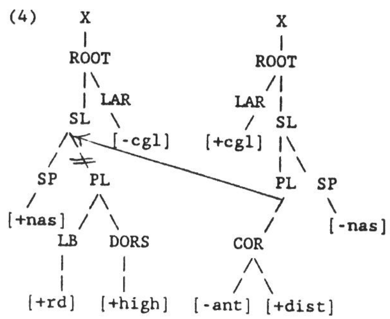
(3)



The tree shown in (3) is taken from Sagey's 1986 dissertation and it differs in a number of details from the tree given in Clements's study. I shall have something to say about these differences below.

In conformity with what is now common practice Clements adopted McCarthy's 1979 suggestion that the feature complements of the different sounds must be formally distinguished from the timing slots. Accordingly Clements represented a sequence of speech sounds as consisting of two parallel sequences of elements -- one composed of timing slots and the other of feature trees. In (4) each capital letter X at the top represents a timing slot and the feature complexes associated with the different timing slots are represented by the trees headed with the node labeled ROOT.

(4)



Given a representation of a phonological sequence like that in in (4) we can postulate that assimilation processes should be formally characterized by means of spreading nodes in the tree of one segment to an adjacent segment. An immediate consequence of this decision about the formalism is that a given

rule can spread only a subset of features dominated by a node in the feature tree; other subsets of features cannot be assimilated in a single rule. For example, in (4) the two features [-ant] and [+dist] can be spread because they are exclusively dominated by the Place node, but it is impossible to spread in a single rule the feature set [-ant] and [-nas], because there is no single node in the tree that exclusively dominates these two features. Two distinct rules will be required for the latter type of assimilation.

As already noted, the groupings of features in the tree shown in (3) are taken from Sagey's 1986 dissertation and differ in significant respects from those that were originally proposed by Clements. Clements's groupings were of two kinds. On the one hand, he had groupings such as Laryngeal which combined features such as voicing, constricted glottis and spread glottis; i.e., features that are executed by a given articulator. On the other hand, he also had groupings such as Place and Manner which combined together features executed by different articulators. Clements makes little of this striking difference, because for him the main determinants of feature grouping are aspects of how the features function in phonological rules. The fact that some feature groupings have straightforward phonetic correlates is, for Clements, an interesting side-product, but not a fundamental criterion for feature groupings. It is not formally reflected in the shape of his feature tree.

This is one respect in which Sagey's 1986 dissertation departs from Clements's pioneering study that was the main source of inspiration for Sagey. In Sagey's framework explicit recognition is given to the fact that each feature is executed by a particular articulator; e.g., backness is executed by the tongue dorsum, nasality by the soft palate, etc. Formally this fact is expressed by grouping together features executed by a specific articulator under a node labelled with the name of the articulator, regardless of other considerations. This procedure results in a number of nonbranching nonterminal nodes in Sagey's feature tree (3), and the question arises whether such nodes -- specifically, the Soft Palate node which dominates only the feature [nasal] -- should not be eliminated from the tree in view of the fact that for purposes of characterizing assimilatory processes such nonbranching nodes are useless. Sagey defends this apparent redundancy in her system on the grounds that her feature hierarchy "contains a class node for each independently functioning articulator . . . Since the soft palate is an independent articulator, there is a class node in the hierarchy for the soft palate. Since the soft palate node dominates only the feature [nasal], there will be no evidence for it from spreading two features at once . . . Nevertheless I will maintain the hypothesis that there exists a class node for the soft palate articulator." (pp.47-8).

An examination of (3) readily shows that the majority of features are articulator-bound in the sense that they are invariably executed by a particular articulator. Thus, the feature [nasal] is always implemented by the Soft Palate, whereas [round] is executed by the lips. By contrast features such as [continuant] or [consonantal] are articulator-free in that different articulators are capable of executing them. I shall use the term stricture features to designate this class of features instead of Clements's term manner features because the latter term has been used for generations so as to include such articulator-bound features as [voice] and [nasal].

The stricture features are represented in the Sagey tree (3) directly below the root node without an intervening articulator node above them. Since for the stricture features no articulator is provided by the feature tree geometry, a special device must be introduced to stipulate the articulator that in each instance executes these features. Following Sagey I shall adopt for this purpose the device of a pointer that connects the root node to the articulator that executes the stricture features. It is essential to note that the pointer is interpreted by Sagey to imply that all stricture features -- i.e., all terminal features dominated directly by the Root node -- are executed by the articulator(s) at which the pointer points.

The pointer formalism not only expresses the fact that all stricture features are executed by the same articulator(s), it also reflects the different roles that different stricture features play in assimilatory processes. It has been pointed out by McCarthy 1988 that two of the stricture features -- the so-called major class features [consonantal] and [sonorant] -- behave rather differently than all other features. In McCarthy's words "the major class features do not assimilate, reduce or dissimilate except in conjunction with processes that affect the entire segment." (p. 97) This observation poses the obvious formal question as to how a feature tree such as that shown in (3) would have to be designed in order for the major class features to exhibit this special behavior of assimilating, dissimilating, etc. only when these processes affect the entire segment. McCarthy's answer is that "the major class features should not be represented . . . as dependents of the Root node <as they are in (3), for then -- mh> they would be expected to spread, delink and so on just as other features do. Instead, the major class features should literally form the Root node, so that the Root node ceases to be a class node and instead becomes a feature bundle itself. . .<Once this is done-- mh> all the other features are . . . in a <u>dependency</u> relation . . . with the major class features. This means that any operation of the class features -- spreading, for example -- implies an operation on the features subordinate to the root." (p. 97)[2]

Specifically McCarthy proposes that the top portion of the feature tree (3) should be reorganized as shown in (5).

(5)

```
           son
           cons
          / | \ .
         /  |  \  .
        /   |   \    .
       /    |    \     .
     LAR  PLACE [cont] [nasal]
```

The major class features [consonantal] and [sonorant] are not only related in

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2. McCarthy adopts here an idea originally advanced by Schein and Steriade 1986.

being superordinate to other features; they are also subject to special co-occurrence restrictions.

As shown in (6) of the four possible classes generated by the two major class features [consonantal] and [sonorant] only three exist; the feature complex [-consonantal, - sonorant] is excluded.

(6)

+consonantal, +sonorant:	liquids, nasals
+consonantal, -sonorant:	obstruents
-consonantal, +sonorant:	vowels, glides
*-consonantal, -sonorant:	unattested

The absence of [-consonantal, -sonorant] segments is due to the phonetic nature of the two features. Nonconsonantal segments are articulated without a major constriction in the central passage through the oral cavity, whereas in order to produce a nonsonorant it is necessary to generate inside the vocal tract pressure that exceeds that of the ambient atmosphere. Such pressure, however, cannot be generated without a closure or a constriction in <u>every</u> passage connecting the lungs to the air outside the vocal tract. Nonsonorants must therefore always be [+consonantal]. Thus once again phonetic and grammatical consideration go hand in hand, both types of consideration require that the major class features be treated separately from other stricture features.

Each of the terminal features in the tree (3) represents a specific phonetically relevant behavior. The only means whereby these behaviors are executed are, of course, the different articulators, i.e., the movable parts of the vocal tract. This anatomical fact is formally reflected in the feature tree by grouping together under a single nonterminal node the features executed by each articulator and labelling the nodes with the name of the articulator. For the stricture features, such as [continuant] or [consonantal], which are not invariably executed by a particular articulator, it is necessary in each instance to stipulate the articulator that actualizes the feature in each instance. As noted above the stipulation is implemented with the help of the pointer. It is in this way that the tree formally reflects the difference between the articulator-bound and articulator-free features. I shall now try to exhibit a number of the further consequences of the formal apparatus developed to this point. As these consequences are both true and somewhat unexpected, they provide additional evidence for the reality of the proposed apparatus.

As shown in (5), McCarthy 1988 (cf. p. 105) includes among the stricture features -- i.e., among the features dominated directly by the root -- the two features [continuant] and [nasal]. He specifically excludes the feature [lateral] and locates it among the features executed by the Coronal articulator. I shall now try to show that this is incorrect and that [nasal] is not a stricture feature, whereas [lateral] is a stricture feature.

My first argument is that from a purely phonetic point of view the two features differ. The feature [nasal], as already remarked, is always executed by the soft palate articulator. By contrast the feature [lateral] is executed not only by the coronal articulator but also by the dorsal articulator. Ladefoged and Maddieson 1986 describe the articulation of such a noncoronal lateral by a speaker of the New Guinea language Mid-Waghi as follows: "It was possible to see that the tongue was bunched up in the back of his mouth with the tip visibly retracted from the lower front teeth. The body of the tongue was visibly narrowed in the central region and presumably also further back where it could not be seen. The only articulatory contact was in the back of the velar region in much the same position as for a velar stop and, according to the speaker, air escaped around both sides of this contact in the region of the back molars." (pp. 104-f.)

Since the feature [lateral] can be executed by at least two articulators -- by the coronal articulator as well as by the dorsum -- it would be inconsisten to represent the feature [lateral] as being dominated by the Coronal articulator in the universal feature tree. Rather like the features [continuant] and [strident], [lateral] has to be grouped among the stricture features.

In an influential paper Juliette Levin 1988 has argued that "the attestation of noncoronal laterals in the phonetics of various languages does not bear on the coronal hypothesis unless it can be shown that such segments . . . must be treated as noncoronals by phonological processes." (p. 10) Levin then proceeds to show that in a number of languages where dorsal laterals are phonetically attested the phonological processes of the language require us to assume that these laterals are underlyingly Coronal, rather than Dorsal. She concludes from this that the feature [lateral] must be directly dominated by the Coronal node in the universal feature tree. If Levin is correct we would then have one bona fide example where purely phonetic considerations lead to different conclusions than considerations of a grammatical/phonological nature. Work by Michael Hegarty, which I shall review here, shows, however, that point of articulation assimilation in the languages of the Iberian peninsula -- Basque, Catalan, Spanish -- requires us to treat [lateral] as a stricture feature, notwithstanding the fact that in these languages all laterals are coronal. On Hegarty's account, the parallelism between phonetic and grammatical considerations is not broken by the laterals.

I shall try to show below that Hegarty's account is indeed correct. At this point I shall assume this conclusion and modify the feature tree accordingly. In the modified tree (7) I have also shown the feature [nasal] as dominated by the Soft Palate articulator. To this point the only reason adduced for this treatment is the purely phonetic consideration mentioned by Sagey; i.e., that the Soft Palate is the only articulator that implements the feature [nasal].

(7)

```
                      [ son  ]
                      [ cons ]
                  - - -/ |  \ .
   SOFT PAL          /  |   \   .  .
      |             /   |    \       .
      |            /    |     \        .
   [nasal]      LAR   PLACE  [cont] [lateral]
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Since the feature [lateral] has been placed in the tree next to [continuant] among the subordinate stricture features it might be expected that there will be commonalities in the behavior of these two features. This expectation is borne out by, among others, the well known fact that vowels and glides never exhibit contrasts between [+/-continuant], [+/-lateral], or [+/-strident]; i.e., for nonconsonantal sounds none of the subordinate stricture features functions distinctively. We express this fact formally by the constraint (8).

(8) In nonconsonantal sounds there are no stricture features directly dominated by the root of the feature tree.

Among the innovations introduced by Sagey the one with perhaps the most far-reaching consequences is the pointer device that signals the major articulator(s) of a speech sound. Sagey remarked (p. 207) that "in every segment the root node "points" to an articulator . . . (It may point to one or more than one.)" In her practice, however, -- in that of other worders who have followed Sagey -- the pointer was often omitted, and this has resulted in misunderstandings in a number of instances. I therefore propose (9) as a well-formedness condition on representations of speech sounds.

(9) Every speech sound has one major articulator; it may have several.

An immediate consequence of proposition (9) is that at least one of the six (five) articulators must be actively involved in the production of every speech sound: sounds in which none of the articulators is involved -- i.e., in which the pointer fails to point to at least one articulator -- are ruled out as a matter of principle. This is obviously a plausible condition to place on representations, but of course not a necessary one.

When speech sounds are examined from the point of view of their major articulator it is noticed that consonantal sounds invariably have as their major articulator one of the three PLACE articulators: labial, coronal, or dorsal. I shall express this formally by the constraint (10).

(10) The major articulator of a consonantal speech sound is one of the PLACE articulators.

Implicit in this constraint is the proposition that there exists a PLACE node in the feature tree. If further research should confirm the correctness of restriction (10) then the restriction constitutes an independent argument for the reality of the PLACE node in the feature tree, an argument that is independent of the facts of "place"-assimilation that were used by Clements and others to justify the existence of the PLACE node in a feature tree.

Constraint (10) holds only for consonantal sounds, it does not hold for nonconsonantal sounds. We should therefore find as many classes of nonconsonantal sounds as there are articulators. As shown in (11) this prediction appears to borne out by the facts.

(11)	Larynx (glottis)	[h], glottal stop
	Tongue Root	pharyngeals and uvulars, advanced tongue root (ATR) vowels
	Soft Palate	Skt. anusvara, nasal glides of Japanese, Choctaw, Malay, etc. (Trigo 1988)
	Labial	[w]
	Coronal	[j]
	Dorsal	In many languages the glides represented as [w,j] have the dorsum as their major articulator; [w] is [+high, +back], [y] is [+high, -back]. Dorsal glides without further specification have been documentedin Australian languages (Hale) as well as in Mandarin Chinese, where these sounds appear phonetically in onsets of phonologically vowel-initial morphemes. (Bao, 1988) The dorsal articulator is the major articulator of vowels. "By vowels we generally mean a group of sonorant sounds which are formed with open mouth and dorsal articulation of the tongue, including also their voiceless cognates." (Sievers, 1901, p.79)

The existence of nasal glides, i.e., of glides whose major articulator is the SOFT PALATE, has been extensively documented in Trigo's 1988 dissertation. The nasal glides provide evidence in support of Sagey's suggestion that the terminal feature [nasal] must be dominated by its own articulator node, for if [nasal] were treated as a stricture feature and were represented as being directly dominated by the root of the feature tree (cf. (5)), there would be no major articulator specified in the representation of nasal glides. But this would be a violation of the well-formedness condition (9), which requires that every sound have at least one major articulator. Thus, the feature organization in (5) and the well-formedness condition (9) cannot both be correct. This problem does not arise in a framework like that of Sagey where the feature [nasal] is represented as being dominated by its own articulator the SOFT PALATE.

The requirement that each sound must have a major articulator also plays an important role in accounting for a variety of phenomena that result from a process that McCarthy, following Clements, has termed debuccalization and that consists in the deletion of the PLACE node from a tree. As an example consider the process whereby obstruents in certain contexts are replaced by the glides [h] or [?]. Given the representations proposed above this process is naturally characterized as being due to debuccalization; i.e., to the deletion of the PLACE node. Since obstruents are always nonnasal we must assume that the Soft Palate articulator is not included in their representation. Thus, after the deletion of the PLACE node, obstruents emerge as consonantal sounds with a single articulator, as illustrated in (12).

```
(12)          [+cons ]                          +cons
              [-son  ]                          -son
              /  |  \                  --->     /  |
             /   |   \                         /   |
          LAR [+cont] PLACE                 LAR [+cont]
          / |           |                   / |
         /  [+spgl]    COR                 /  [+spgl]
   [+stiff]                          [+stiff]
```

The resulting representation is not well-formed. It lacks a major articulator, for by eliminating the PLACE node we have also eliminated the major articulator of the sound. The obvious move is to postulate the repair convention (13a).

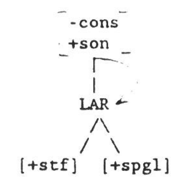
(13a) In a segment with a single articulator node, this node is also the major articulator.

Since in the case under discussion the Laryngeal articulator is the only articulator present it automatically is made the major articulator by having the pointer point to it. This move, however, produces a violation of restriction (10) which rules out consonantal sounds whose major articulator is the LARYNX. We solve this by postulating with Trigo the repair convention (13b).

(13b) Segments without PLACE node are [-consonantal]

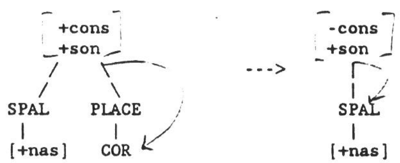
This in turn has the further consequence that all nonconsonantal segments are also sonorant -- in conformity with (6) above -- and that in conformity with (8) they also lack any stricture features dominated directly by the root. In sum, given the independently justified constraints (6), (8) (9) and (10) and the repair conventions (13) the result of the debuccalization in (12) is turned into (14) which is the proper representation of [h].

(14)



We next examine the effects of debuccalization on a coronal nasal illustrated in (15).

(15)



As shown in (15) since nasal consonants have no distinctive laryngeal compononent, the deletion of the PLACE node leaves the SOFT PALATE as the only articulator in the tree. The repair convention (13a) will automatically establish the SOFT PALATE as the major articulator and convention (13b) will specify the sound as [-consonantal]; i.e., a glide.

A prediction of the feature tree framework that has been presented here is that debuccalization should replace obstruents with laryngeal glides, whereas nasal consonants should be replaced with the nasal glide. Trigo's (1988) dissertation provides much evidence that supports this prediction.

Among the examples of debuccalization discussed by Trigo is that of the Kagoshima dialect of Japanese, from which the examples in (16) are drawn.

(16)	obi	o?	'belt'	kami	kaN	'god'	kasu	'draft'
	matu	ma?	'pine tree'	inu	iN	'dog'	kaZi	'bell'
	oku	o?	'to put'	karu	ka?	'to cut'	osu	'to push'

Trigo accounts for these facts by postulating the three ordered rules in (17).

(17) a. Delete a word final high vowel after a nonstrident consonant

b. Glottalize nonnasal consonants in syllable coda

c. Debuccalize coda consonants

The examples in the last column of (16) show that high vowel deletion by rule (17a) does not take place after strident consonants and consequently none of the other changes take place in this environment either. As a result of the

glottalization rule (17b) all nonnasal consonants in coda position have a Laryngeal node. According to Trigo this rule is quite general in Japanese dialects where it usually operates word medially and is responsible for the special properties of Japanese geminates. The rule of debuccalization (17c) yields a nasal glide if the syllable-final consonant was nasal, and it generates a glottal stop, otherwise. The facts in (16) thus fully confirm the predictions of the theory.

As Trigo points out this analysis is further supported by the treatment of loanwords in Japanese. In most Japanese dialects a word cannot end in a consonant and an epenthetic vowel is inserted after the last consonant. This is illustrated by the first two examples in (18). The exception to this are foreign words ending with [n] such as the American word Washington, which in Japanese is actualized with a word final nasal glide. Since the glide is nonconsonantal, the vowel epenthesis rule does not apply and the word is pronounced without epenthetic vowel.

(18)	simputomu	kooto	wasintoN
	'symptom'	'coat'	'Washington'

To sum up, there exist phonological phenomena that require for their formal expression a tree structure in which the feature [nasal] is dominated by an articulator node rather than being dominated directly by the root node of the tree.

We turn now to the feature [lateral]. It was noted above that the feature [lateral] could not be placed under the CORONAL node for narrowly phonetic reasons; i.e., because there are well-attested cases of languages where coronal laterals contrast with dorsal laterals. In an interesting still unpublished paper Michael Hegarty 1989 has shown that even in languages where all laterals are coronal it is impossible to treat the [lateral] feature as being bound to the coronal articulator.

Hegarty notes that in many dialects of the languages spoken in the Iberian peninsula there is a rule that renders a sonorant consonant -- i.e., a nasal or a lateral-- homorganic with a directly following obstruent. I have reproduced in (19) the Spanish examples cited by Hegarty.

(19)

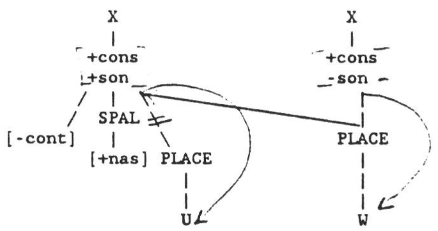
[um pwerto]	'a port'	[el pwerto]	'the port'
[um foko]	'a focus'	[el foko]	'the focus'
[un tio]	'an uncle'	[el tio]	'the uncle'
[un' ciko]	'a boy'	[el' ciko]	'the boy'
[un jate]	'a yacht'	[e jate]	'the yacht'
[un gorila]	'a gorilla'	[el gorila]	'the gorilla'

According to Hegarty "nasals don't always assimilate in place to a following nasal, even when they occur in a rime, as in inmenso and columna . . . nasals assimilate systematically only to [-sonorant] consonants." Hegarty notes further that in Spanish, nasals must have underlying specifications for

PLACE since there are contrasts such as <u>cama</u> 'bed', <u>cana</u> 'grey hair', <u>caña</u> 'cane' where labials contrast with coronals and the latter are distinguished as [+ant] vs. [-ant]. In view of these facts, Hegarty concludes that "nasals assimilate in place to a following [-son] consonant." (p. 20)

The process of assimilation may formally be pictured as shown in (20).

(20)



where U, W represent PLACE articulators

It is to be noted that the assimilation process here is "feature changing" for as shown in the examples (19) all features dominated by the left articulator will be replaced by those of the articulator on the right. This fact should be retained for it is significant for what follows.[3]

Hegarty notes that [l]'s nonlateral counter-part [r] is not affected by assimilation. Hegarty recalls that [l] differs from [r] not only in laterality but also with respect to [continuant]: [l] is [-continuant], whereas [r] is [+continuant]. Since nasal consonants are normally articulated with the same full oral closure as the stops the class of segments undergoing assimilations -- i.e., the nasals and [l], but not [r] -- must be characterized as [-continuant, +consonantal, +sonorant]. And the triggering segment is [+consonantal, -sonorant]. I have included these specifications in (20).

Hegarty next turns to the differences between the assimilation undergone by the lateral and that undergone by the nasals. In the case of the nasals the assimilation takes place before any obstruent, whereas in the case of the lateral assimilation occurs only when the following obstruent is coronal. It is difficult to add restrictions to the rule so that it would not apply to laterals when these are followed by labials and dorsals. A more appealing solution is to impose an output condition on the rule along the lines of McCarthy's 1986 paper on antigemination and the OCP. This would allow the assimilation rule to apply in all cases except where the rule would generate noncoronal laterals, i.e., sounds that are as foreign to the languages under discussion as they are to English.[4]

Having established the possibility of using an output filter on phonological rules, we now inquire how this device can be utilized in dealing with the fact that laterals assimilate only to a following coronal but not to a following dorsal or labial consonant. As Hegarty points out, the key to the solution is provided by Hualde 1988, who studied the identical assimilatory process in Basque. Hualde argued (I quote Hegarty p. 21) that "in order to capture the fact that laterals do not assimilate to labial and velar segments, a constraint such as (21) must be operative:

(21) If a segment bears [lateral], then it must have a coronal node."

If this constraint is interpreted as an output condition of the sort proposed by McCarthy 1986, the assimilation rule would be prevented from applying in cases where a noncoronal lateral would be generated; i. e., in the environment before a labial or dorsal obstruent. Since there is no similar output constraint on the formation of nasals, the assimilation rule will apply to nasals without restriction.[5]

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3. Hegarty argues that at least for Catalan -- and perhaps for the other Iberian languages as well -- in the assimilation process it is not the PLACE node but rather the major articulator node that is spread. Hegarty's argument is based on the fact that in Catalan there are two types of laterals -- velarized ([+high, +back]) and nonvelarized ([+high, -back]). Catalan laterals therefore involve in addition to a major Coronal articulator also a minor Dorsal articulator. The minor Dorsal articulator is lacking in the Catalan obstruents. In view of this, if the Catalan rule of assimilation were formulated so as to spread the PLACE node of the obstruent on to the preceding lateral this would imply incorrectly that the contrast between velarized and palatalized laterals is neutralized before Coronal obstruents. To avoid this incorrect result, Hegarty reformlates the assimilation rule so that it spreads the node of the major articulator, rather than the Place node. As these facts are not directly relevant to the discussion here I have represented the process (20) as being the more familiar spreading of the PLACE node.

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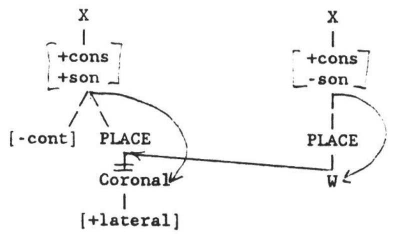
4. The existence of output filters of this sort has been demonstrated by McCarthy 1986 in his paper on OCP effects. In this paper phenomena from a great many languages are studied all of which require the existence of output filters whose main effect is that of blocking the application of a rule if its result would violate the filter. Although work remains to be done in order to elucidate the precise nature of these filters as well as the class of rules that are subject to them, McCarthy's paper puts the existence of such filters beyond question.

5. It might be worth observing at this point that output constraints capture only part of the phenomena normally included under the concept of "structure preservation" as suggested by some writers. For example, it has been shown (see Halle and Kenstowicz 1989) that metrical structure is preserved before noncyclic suffixes, but is always erased before cyclic suffixes. It seems impossible to capture structure preservation of this kind by means of an

Hegarty writes, "Hualde suggests that the constraint in (21) can be captured in feature geometry by making the feature [lateral] a terminal dependent of the coronal node." However, if lateral is a dependent of the coronal articulator, then as Hegarty points out, "the [+lateral] specification will delink upon application of [the assimilation rule- mh] leaving behind a segment not specified as a lateral." Since unlike noncoronal laterals, the nonlateral segments resulting from this application of the assimilation rule cannot be excluded on general grounds, the proposed account collapses if [lateral] is treated as dominated by the Coronal articulator. This is ullustrated in (22).

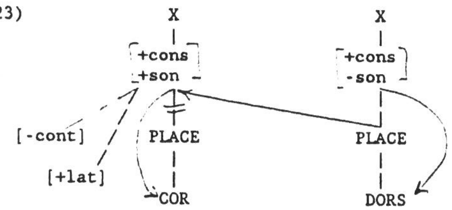
(22)



where W is Labial, Dorsal, Coronal

The difficulty does not arise if, as proposed above, [lateral] is treated as a stricture feature dominated directly by the root of the feature tree. As shown in (23) the application of the assimilation rule to a lateral will produce a dorsal lateral; i.e., a feature configuration that violates the output filter (21), and as noted above, application of the assimilation rule in such circumstances is blocked.

(23)



The behavior of laterals in Spanish as well as in the other Iberian languages discussed by Hegarty thus sustains the proposition that the feature [lateral] is a stricture feature, dominated directly not by an articulator node, but rather by the root node of the feature tree.

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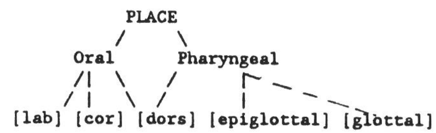
output constraint.

In his paper on gutturals McCarthy (1989) has adduced impressive evidence, most of it from the Semitic languages, showing that the so-called gutturals; i.e., [h ? H 9 X G] function as a class in a great many phonological processes. McCarthy observes (p. 33) that "on the articulatory side, the gutturals are produced by three entirely distinct gestures: a purely glottal one in the case of the laryngeals, a retraction of the tongue root and epiglottis and advancement of the posterioir wall of the laryngopharynx in the case of the pharyngeals; and a superior-posterior movement of the tongue dorsum in the case of the uvulars." He concludes from this that "the commitment to classifying consonants in terms of major articulator is clearly in error, at least as far as the gutturals are concerned. Because the gutturals are produced by three different articulators, they would require three different articulator features. Articulator-based feature theory can describe sets of articulatorily distinct consonants in a stipulative way; for example, the labials and velars together are {[labial], [dorsal]}. But a consistent classification like gutturals, which acts together in a variety of unrelated phonological processes, cannot be sensibly characterized by an arbitrary disjunction like {[dorsal], [radical], [laryngeal]}. We must therefore reject articulator-based features, at least as the overriding organizational principle, and look elsewhere for an explanation for the behavior of the gutturals." (p. 36).

McCarthy therefore proposes that below the PLACE node the feature tree should have the structure in (24).

(24)



I see the situation somewhat differently from McCarthy and would briefly like to sketch this different view, which is fully compatible with the articulator-based framework presented above. I note first that, as observed by McCarthy, "phonetically, all gutturals except ? are quite glide-like, and even ? is definitionally a glide in Chomsky and Halle 1968." (p. 3) My first proposition is therefore that

P-1. Gutturals are [-consonantal].

My examination of the x-ray tracings as well of other evidence adduced by McCarthy as well as well Czaykowska-Higgins, Trigo, and others leads me to the conclusion that both the uvulars and the pharyngeals are produced with a major constriction on the bottom of the pharynx, and that they differ in this respect from [h ?] which lack this constriction. Following an established terminological tradition I shall label the feature involved as [Constricted Pharynx], and I assume that this feature is implemented by the Tongue Root articulator. I therefore postulate P-2.

P-2. Pharyngeals and uvulars are [+Constricted Pharynx], [h,?] are [-Constricted Pharynx].[6] .

The question that must be answered next is the manner in which pharyngeal constriction is to be characterized in the feature system. I have assumed here that [Constricted Pharynx] is implemented by the tongue root. This assumption is in conformity with the treatment accorded to the Tongue Root in most phonetic frameworks.

If Tongue Root is to be added to the articulators in the tree, the question arises where it is to be placed among the other articulator nodes. Before answering this question I digress to propose a relabelling of the articulator that executes the features [constricted glottis], [stiff vocal cords], etc. Rather than refer to it as the Laryngeal articulator, it is more accurate to designate it as the Glottal articulator, as was done by McCarthy (1989), cf. (24).

This relabelling makes it straightforward to state my next proposition; i.e., that the Glottal articulator and the Tongue Root node are dominated by an intermediate node labelled LARYNX in view of the fact that it is muscles of the larynx that control both glottal behavior as well as the positioning of the epiglottis and other structures at the upper end of the larynx. This is formally expressed as P-3.

P-3. In the feature tree the features [Constricted Pharynx] and [ATR] are executed by the Tongue Root (TR) articulator; the features [constricted glottis], [spread glottis], [stiff vocal cords], [slack vocal cords] are executed by the Glottal articulator (i.e., the vocal cords). The TR and Glottal nodes are directly dominated by the LARYNX node.

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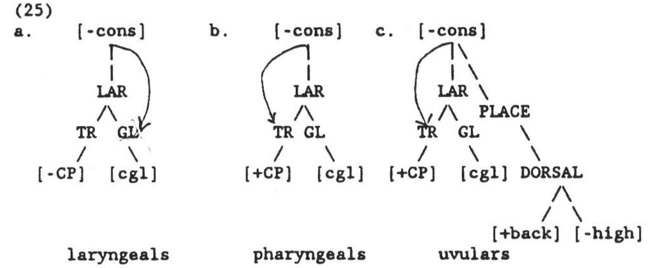
6. Or perhaps have no tongue root involvement whatever

A modicum of support for the suggestion above is provided by the fact that in many languages the Tongue Root features -- both [Constricted Pharynx] (=[CP]) and [ATR] induce noticeable modifications in voice quality. Thus, in some African languages, [-ATR] vowels are said to be pronounced with creaky, bright, brassy voice, whereas [+ATR] vowels are pronounced with breathy muffled, or hollow voice. (See Czaykowska-Higgins 1987 and literature cited there.)

If the three propositions above are adopted, the three types of Semitic gutturals will be represented as illustrated in (25).

(25)



It is obvious that on this analysis, there is no longer any problem about the phonological characterization of the gutturals: they are the glides whose major articulator is laryngeal, dominated by the LARYNX node in the feature tree.

I note finally that as geometric objects -- i.e., disregarding the node labels --the tree in (25c) differs from McCarthy's tree (24) in one respect only: in (24) the terminal node [dors] is connected to two nonterminal nodes, whereas in (25) there are no multiple links from nodes lower in the tree to higher nodes. The difference reflects a difference in the conception of the nature of the uvulars: I regard them as sounds that have the same major articulator, the Tongue Root, as the pharyngeals, whereas McCarthy believes that the major articulator of the uvulars is the dorsum, whereas that of the pharyngeal is the epiglottis. Since our disagreement can thus be localized to our different interpretations of the phonetic data, there is hope that it will soon be settled as the results of the ongoing phonetic investigations into the nature of these sounds become available.

Summary

In the preceding I have viewed the feature tree associated with each speech sound as an abstract object that encodes the intentions of the speaker in producing a particular sound. Since ultimately these intentions are executed by the six articulators which together constitute the human vocal tract, the model that I have proposed is an articulator-based model in the sense that it reflects aspects of the way in which the intentions are communicated to the articulators.

Specifically I have proposed that the intention of pronouncing a speech sound must always include the information whether the sound is [+/-consonantal] as well as an indication of the major articulator, i.e., the articulator that executes obligatory stricture feature [consonantal]. I have proposed moreover that the feature tree has at its root the organization shown in (7), and I have set forth a number of constraints -- those in (6) (8) (9) (10) (13) -- on feature combinations in the tree. I exhibited a number of

consequences of the modified framework that seemed to me to provide support for it. Finally I tried to show that the class of gutturals can be characterized straightforwardly in the proposed articulator-based framework.

I am well aware that I have not addressed a number of well-known difficulties. I have said nothing about the difficulties that have arisen in the characterization of consonantal palatalization before front vowels and glides, or about the characterization of harmony process involving the simultaneous spreading of features of two distinct articulators, e.g., [back] and [round]. Whether an understanding of these unresolved problems is advanced by the proposals I have made here will be decided by the studies to be undertaken in the months and years to come.

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Third draft October 4, 1989, corrected October 7, 10, 1989

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