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Hierarchical features of the International Phonetic Alphabet

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Most American linguists think of the International Phonetic Association (IPA) as a conservative group of traditional phoneticians, whose concerns are very different from those of contemporary phonologists. They may be right in their assessment of the traditionalist nature of many IPA members (although it should be noted that the Council of the IPA now contains several younger linguists); but they are certainly wrong in viewing the concerns of the IPA as being different from their own. Throughout its hundred year existence the main endeavour of the IPA has been to provide accurate phonetic descriptions of languages, based on phonological principles as then understood. The Association's alphabet was devised as a tool to aid in the formulation of such descriptions. The alphabet has been continually revised, and there is today a strong movement to bring the present alphabet more in line with contemporary thought. A convention for this purpose is being held in Kiel, Germany, in August 1989, and all who are interested (whether members of the IPA or not) are welcome to attend. (Further particulars are available from: IPA Convention, Linguistics Department, UCLA, Los Angeles, CA 90024-1543.)

The linguistic foundations of the alphabet are evident throughout its history. In 1900 the IPA published an *Exposé des principes* containing a table showing the recommended alphabet. This table was set up so that it included "les sons distinctifs de toutes les langues étudiées jusqu'ici". (My italics.) The principles mentioned in the title of this and other early publications of the IPA (*Aims and principles*, 1904; *Exposé des principes*, 1905) were all concerned with language teaching. It is not until the 1908 *Exposé des principes* that, in addition to a section "Principes pédagogiques," there is also a section "Principes de transcription pratique." This section notes that: "Pour chaque langue, on représente les sons distinctifs, et ceux-là seuls." Similarly, the 1912 English version, in a section headed "principles of transcription for languages hitherto not transcribed," notes, long before the phoneme became a popular notion: "It is necessary to ascertain what are the *distinctive* sounds in the language, i.e. those which if confused might conceivably alter the meanings of words." (Italics in the original.) The corresponding section in the 1922 *L'Écriture phonétique internationale*

uses the then new term 'phoneme' saying: "Pour chaque langue, on représente les *phonèmes* ou sons distinctifs, et ceux-là seuls." (Italics in the original.). The latest (1949) edition of the *Principles* makes as its first point: "There should be a separate letter for each distinctive sound; that is, for each sound which, being used instead of another, in the same language, can change the meaning of a word. "

The second principle in the current edition is also relevant to contemporary phonological concerns, in that it presupposes the existence of a set of universal phonetic categories, making it meaningful to equate sounds in different languages. It says: "When any sound is found in several languages, the same sign should be used in all. This applies also to very similar shades of sound." This principle is especially important when taken into account with another IPA practice which has never been formally stated as a principle, perhaps because it is regarded as too obvious to mention. This is the principle that the symbols of the alphabet should be defined in terms of general phonetic categories very much of the kind that we now regard as features. Phonetic theory in the early days of the IPA was greatly influenced by the work of Sweet and Bell, both of whom had developed systems for classifying all the sounds that were known to be able to distinguish meanings in the world's languages. Bell's *Visible Speech* (1867) and Sweet's *Handbook of Phonetics* (1877) provided iconic symbols for showing the combinations of articulatory elements present in a sound. These same elements (or at least a subset of them) were used to define the symbols of the alphabet. Throughout its history the alphabet has consisted of symbols defined in terms of intersections of phonetic categories (features). Most of the symbols are defined by the terms naming the rows and columns of the charts, and by the convention that when there are two items in a single cell the first one designates a voiceless sound (if there is a single item in a cell it is always voiced). In addition a few symbols and several diacritics are defined by supplementary notes. The whole work -- principles, charts, symbols and notes -- constitutes the IPA's theory of phonetic description.

Given this background we may now compare an IPA description with a feature specification of the kind that is nowadays more common. The location of [m] in the chart explicitly indicates:

- + voiced
- + bilabial
- + nasal

and, by means of the labels along the lefthand edge of the chart, the fact

that this is a consonant made with the pulmonic airstream mechanism. In much the same way, Chomsky and Halle (1968:5) note that they will use symbols as "informal abbreviations for certain feature complexes." For them this symbol would be a shorthand way of designating the feature values:

- + voiced
- + nasal
- + anterior
- coronal
- + sonorant
- etc.

In both cases several other feature specifications are implied. IPA [m] implies [- dental, - alveolar, etc.; - implosive, -click, etc.]; and in SPE (Chomsky and Halle 1968), it is made clear that there are also a number of other features such as [Glottalic] the values of which, like some of those noted in (2), can be determined by marking conventions. Bearing these two approaches in mind, we may consider the extent to which the similarities between them could be increased in any future revision of the IPA *Principles*, symbols, charts, and accompanying notes.

The nature of feature systems

The first point to emphasize is that the two approaches are very different in some of their basic premises. It is true that they both describe segments in terms of features, and in some cases, such as Nasal, they both use the same terms. But, as has been shown by Halle and Ladefoged (1988), the hierarchical organization of the IPA feature set is very different from that of SPE or contemporary phonologies. In particular, the IPA has separate charts for vowels and consonants, whereas it is a major point of SPE and other phonologies in the same tradition that both vowels and consonants should be described in terms of the one set of features. As will be made clear below, I think both positions are correct. Another major difference between the two theories is that the IPA has little internal organization to the set of place categories other than (in some charts) the grouping together of some immediately adjacent places. Contemporary phonologies (e.g. Clements 1985, Sagey 1986, Halle 1988) recognize that there is far more structure imposed by the articulatory system. Considerations such as these led Halle and Ladefoged (1988) to propose that the major features that should be characterized by the symbols of the alphabet should be as shown in figure 1.

Figure 1. The hierarchical organization of the major features.

These are clearly the major features of segmental phonology; but, equally obviously, they are not sufficient for describing the sound patterns of languages. In the remainder of this paper I will sketch some of the additional structure that I consider necessary for phonological specifications. I will then consider briefly how this information should be regarded in a revised version of the International Phonetic Alphabet.

A hierarchical feature structure

An overview of the proposed structure is given in figure 2. This tree structure represents a conjecture about the phonological resources, the features and their relations, that are available to the languages of the world at the level of the segment. It should be emphasized that this figure gives only a tentative, incomplete view of the relations among features. Nevertheless, it forms part of a statement defining the phonological possibilities that can occur. The arrangement of features into a tree structure has also been used by phonologists for other purposes, notably the grouping of properties that co-occur in spreading rules. In this paper, however, the aim is simply to provide a way of representing the major constraints on phonological segments. This aim is very much in the spirit of the IPA tradition. As we have noted, the International Phonetic Alphabet has always been an attempt to

Type	Hyper feature	Major node	Feature	Traditional term	Brief description
Auditory			Voice	Voiced	periodic low frequency energy
				Voiceless	- absence of such energy
			Grave		aperiodic low frequency energy
					- absence of such energy
			Sibilant	Sibilant	aperiodic high frequency energy
					- absence of such energy
			Height	High vowel	low F1
				Mid-high vowel	- mid low F1
				Mid-low vowel	- mid high F1
				Low vowel	- high F1
			Brightness	Front unrounded	high (F2' - F1)
				Back rounded	- low (F2' - F1)
			Sonorant		periodic well-defined formants
					- no periodic formant structure
Physiological		Place	Labial	Rounding	decreased lip opening
				Rounded	- spread lips
				Unrounded	protruded
			Protrusion	Labial	- neutral
				Labiodental	- retracted lower lip
				Linguolabial	(tongue between lips)
				Laminal	laminal
			Coronal	Apicality	- apical
				Retroflex	- sublaminal
			Anterior	Dental	advanced
				Alveolar	- neutral
			Dorsal	Postalveolar	- retracted tongue tip/blade
				Palatal	front
			Front	Front	- back tongue body
				Back	high
			High	Velar / high vowel	- mid
				Uvular / mid V	- low tongue body
			(Low)	Pharyngeal / low V	retracted tongue root
				Epiglottal	- advanced tongue root
		Manner	Interrupted	Stop	complete closure
				Fricative	- nearly complete closure
				Approximant	- approximation of articulators
			Lateral	Lateral	predominantly lateral airflow
				Central	- no lateral airflow
			Dynamic	Trill	held gesture
				Tap	- vibrating
				Flap	- ballistic
			Nasal	Nasal	- ?
					lowered soft palate
		Laryngeal	Stiffness (Slack)	Creaky	- raised soft palate
				Modal	stiff
				Breathy	- neutral
			Glottal aperture (Closure)	Aspirated	- slack vocal cords
				Unaspirated	open
		Airstream	Pulmonic	Fortis	- narrowed
				Lenis	- closed vocal cords
				Implosive	segmental lung power
			Glottalic movement	Ejective	- no increased lung power
				Click	downward
		Velaric	Click		- no glottal movement
					- upward glottal movement
					oral suction
					- no oral suction

Figure 2. A hierarchical arrangement of features forming part of a definition of the set of possible phonological segments in the languages of the world.

represent all and only the distinctive sounds in the world's languages. We would now like to go a step further and list not just the sounds but also the features that characterize them, together with the constraints on feature interaction. In this sense figure 2 is a first step towards defining the possible phonological segments in the world's languages.

In order to serve this purpose a great deal has to be added to the tree structure in figure 2. In the first place we need to state the conventions governing the possible paths through the tree; but at the moment we do not know what these are. The general convention for reading the tree structure is that the maximum possible set of phonological segments is achieved by taking each path through every node except the terminal nodes (the features) where one of a set of choices has to be made. But this convention does not apply to the nodes in the third column. The Place node dominates a set of features such that for most sounds only one path has to be selected, but for some sounds more than one may be selected, and, arguably, for some, such as a glottal stop, none of the options is selected. Similar remarks apply to the choice of airstream mechanism, as will be elaborated later.

There are several other cases, such as the properties dominated by the Manner node, in which the inter-relations are too complex to be given in the form of a tree structure. There are also cases for which the level of our ignorance is such that we cannot even indicate the immediately superior nodes for a given sound (e.g. in the description of linguolabial consonants; Maddieson 1987). It is readily apparent that figure 2 is far from complete, and numerous additional statements are needed to define the limits of possible feature combinations. However, this should not cause us to overlook the fact that the figure does list many of the possibilities, and many of the required hierarchical properties *are* formalized by the lines indicating the necessary dominance relations.

As a further guide to the interpretation of this figure, very rough descriptions of the features are given in the extreme right column, the properties connected by dashes indicating sets within which choices must be made. Note that the choices are often binary, but on a number of occasions (e.g. for Protrusion and Apicality) there are three possible terms. To the left of these, in the penultimate column, there is a set of italicized terms indicating the traditional (usually IPA) terms. These terms do not have any formal standing within the theory of phonetic description being advanced here. They are simply useful (and familiar) terms summarizing certain feature combinations. Thus *Postalveolar* is equivalent to [-anterior, +coronal], and *Velar* to [+high, +dorsal].

The first and most important difference between the trees in figures

1 and 2 is that the latter tree contains another whole branch specifying auditory properties. All the features in figure 1 are ultimately defined in terms of actions of the vocal organs. But there are many important natural classes of sounds that arise because sounds have certain auditory properties in common. It is somewhat ironic that this great insight of the Prague school, much touted by Jakobson, Fant and Halle (1951), should now be overlooked by the phonologists who are their successors. The present situation arises partly because of the view of phonology first seen in SPE (Chomsky and Halle 1968), in which features are considered to be mental entities. From this point of view it is just a matter of exposition as to whether features are defined in articulatory or acoustic terms. But this is simply not true. Segments get grouped together into natural classes not because of some general mental property, but because of specific properties relating to the way sounds are heard, or to the way they are produced. Of course all features have both articulatory and acoustic properties in the sense that features are linguistic units that characterize the lexical items of a language. These lexical items have to be capable of being both spoken and heard. But it does not follow from this that we should consider the linguistic function of a feature as being required in both domains.

I do not want to overstate my case in this matter. Chomsky and Halle are correct in considering that for many aspects of sounds the correlation between the auditory properties and the physiological properties is so great that it really does not matter whether we define the feature in auditory or articulatory terms. Thus the feature Voice can be defined equally well in either way as is done by Jakobson and Halle (1956:30): "acoustically -- presence vs. absence of periodic low frequency excitation; genetically -- periodic vibrations of the vocal cords vs. lack of such vibrations." In the list in figure 2 I have, somewhat arbitrarily, chosen to put Voice among the auditory features.

No such arbitrary choice is possible for some features, such as Nasal. The articulatory correlate is clear (lowering of the velum); but despite enormous pressure from speech pathologists, who need a simple way of measuring the degree of nasality of a sound, nobody has been able to suggest an acoustic attribute common to all nasalized sounds. Again, I am not saying there are no acoustic correlates of nasality; obviously there are, else we would not be able to hear whether a given vowel is oral or nasal. But from the point of view of how segments can be grouped into natural classes, it is not the diverse acoustic properties that are the basis of the grouping, but the fact that all nasal sounds are *produced* with something in common.

Auditory feature definitions

A large proportion of the features required for phonological purposes are defined, as Nasal and the other features shown in figure 1, in terms of articulatory properties. But, just as there is no definition of the acoustic correlates of Nasal that is useful for phonological purposes, so there are other features that have no phonologically useful articulatory correlates. We will begin our more detailed examination of the features listed in figure 2 by considering these auditory features. One of the most well known is the feature Grave, which groups some Labial and Dorsal sounds in accordance with their spectral characteristics. Sounds such as [p,k,f,x] are produced in very different ways, but they sound similar because they have a comparatively large amount of aperiodic acoustic energy in the lower part of the spectrum. This similarity is reflected in morphological alternations such as those in Bantu languages (e.g. Rutooro; Ladefoged, Glick and Ciper 1972) and historical changes such as English [x] to [f] in words such as 'rough, tough,' a change that is completely inexplicable in articulatory terms.

Chomsky and Halle discarded the feature Grave because they found it did not provide a satisfactory basis for characterizing differences in place of articulation. This is undoubtedly true; from an articulatory point of view the feature Grave does not distinguish the appropriate natural classes. But this does not mean that it fails to characterize a natural class of sounds from an auditory point of view. Throwing out Grave just because it does not have a useful articulatory correlate is as bad as it would be to throw out Nasal just because it does not have acoustic correlates that themselves form a basis for a natural class.

Note that the feature Grave as proposed in this paper is not exactly the same as the feature proposed by Jakobson, Fant and Halle (1951). Their definition was "the predominance of one side of the significant part of the spectrum over the other." It was intended to include both consonants and vowels. My feature Grave is in practice restricted to obstruents (and, perhaps, voiceless approximants) because it stipulates that the auditory characteristic of a Grave sound is that there is salient *aperiodic* energy in the lower part of the spectrum. In speech, this type of energy occurs only in stop bursts and fricatives (and, perhaps, a voiceless labial-velar approximant). There is no auditory property of this sort that links particular vowels with particular consonants. (But there are, of course, links between particular vowels and consonants specified by the articulatory features High, Low and Back.)

Note also that this definition of Grave implies that [- grave] sounds are not necessarily Acute in the old Jakobsonian sense. All sounds that do not have a significant amount of aperiodic energy in the lower part of

the spectrum are [- grave], irrespective of whether they have a significant amount of aperiodic energy in the upper part of the spectrum or whether they do not have any aperiodic energy at all.

Another auditory feature that is of importance in grouping consonants I have here called Sibilant, following the traditional phonetic usage. It is not exactly equivalent to the Jakobsonian feature Strident in that the feature Strident has also been used to distinguish [t,v] from [ʧ,ʤ], thus resulting in the rather unnatural class of strident sounds [t,v,s,z,ʃ,ʒ]. So as to make the difference in definition plain, I have retained the traditional term Sibilant, which has long been used (e.g. by Holder 1669, and many phoneticians after him) to identify the class of sounds [s,z,ʃ,ʒ].

It is interesting to consider whether it might be possible to give an articulatory definition of this feature, in that Sibilant sounds are always pronounced with the jaw raised so that there is a very narrow gap between the upper and lower front teeth. The high frequency aperiodic acoustic energy that gives rise to the auditory characteristics of this feature is due to the jet of air striking this narrow gap (Catford 1977, Shadle 1985). However, the fact that sibilant sounds have an articulatory attribute in common is an unlikely cause for their acting together in historical changes and morphological alternations. There is no evidence showing that jaw position is a salient characteristic of sounds causing them to be grouped together, whereas the auditory grouping of these sounds is evident in the perceptual confusion data of Miller and Nicley (1955) and its reanalysis by Shepard (1972), and in the perceptual similarity judgments reported by Ingram (1975).

It is appropriate at this point to consider what is at issue in claiming that a certain feature (e.g. Sibilant) should be defined in auditory rather than acoustic terms. It is not a matter of there is or is not a feature of this kind. There is little doubt that sibilants form a natural class of sounds that act together in phonological rules. Nor is it a matter of formal evaluation of rules. Given that there is a feature sibilant the system for evaluating its use within a phonology will be the same irrespective of its phonetic attributes. What is at stake is whether the auditory definition provides a better explanation for the grouping than a definition in terms of the articulatory attributes. Until there is some evidence for the shared articulatory properties being the reason for this grouping, it seems preferable to continue to maintain that the well attested salient auditory characteristics are the basis for the natural class.

The most outstanding features of the auditory type are properties of vowels. A problem that arises in discussing these features is that it

has not been generally recognized that vowels have both articulatory *and* auditory properties. Hence the same name has been used for something that should be regarded as two distinct features. I will use the term (Auditory) Height to refer to an attribute that has as its acoustic correlate the frequency of the first formant. The other auditory feature of vowels is here called Brightness, a term ("Helligkeit") used by Trubetzkoy (1929, 1939), and more recently by Fischer-Jørgensen (1985). The acoustic correlates of Brightness may be taken to be the difference in frequency between the first formant and F2', a form of the second formant modified so as to account for the influence of the third formant. Algorithms for determining F2' have been given by Bladon and Fant (1978). From a physiological point of view, Brightness is a combination of all three articulatory vowel features, Front, Back, and Round. High front unrounded vowels have the highest value of Brightness, low back neutral vowels have a mid value and high back rounded vowels have the lowest value.

The explanatory power of the two auditory features for vowels is best exemplified by the dominance of the five vowel system [i e a o u]. Languages as diverse as Swahili, Spanish, and Hawaiian have five vowels, with qualities something like [i e a o u]. These and only these vowels are used by approximately 20% of the world's languages (Maddieson 1984). From an articulatory point of view, there is no reason why front unrounded and back rounded vowels should be more common than the reverse combinations. Phonologists who regard all features as having only articulatory definitions have no explanation for the remarkable facts of vowel distribution. There should be no doubt that in order to form the correct phonological classes of vowels these sounds have to be characterized in both physiological and auditory terms. The action of the body of the tongue in the production of a vowel is specifiable in terms of physiological features that are also applicable to consonants (and thus show the relations between vowels and consonants). But this does not preclude there being additional auditory features that are applicable only to vowels.

The remaining auditory feature listed in figure 2 is Sonorant. This is another very necessary feature that it is hard to define in articulatory terms. The notion 'spontaneous voicing' (Chomsky and Halle 1968) does not get at the essence of what it is that causes vowels, nasals, laterals and some approximants to be grouped together. Better articulatory statements can be made in terms of the function of the articulatory system as a whole: sonorant sounds are those in which the vocal cords are vibrating and there is no significant build up of oral pressure. But there is no evidence that vocal cord vibrations plus lack of

pressure form a salient characteristic. Sonorant sounds are clearly related by having a periodic, well-defined, formant structure. Their grouping is not because they are made alike, but because they sound alike.

There are almost certainly other auditory features that will have to be included in future lists such as that in figure 2. One of these is the feature Rhotacized, which is associated with a lowering of the frequencies of the third and fourth formants. As has been shown by Lindau (1985) many forms of *r* share this characteristic. The fact that (as she also shows) some forms of *r* do not does not preclude rhotacization being an auditory feature that links some sounds in a natural class. Another possible auditory feature is Liquid, grouping together some kinds of rhotic and lateral sounds.

The organization of articulatory features

As most of the proposed articulatory features are well known, we need not consider explicit definitions of all of them. There is, however, much to be said about their hierarchical organization. The basic division into five hyper-features reflects the standard practice of articulatory phonetic description as seen in many textbooks. Abercrombie (1957) for example, notes that sounds can be described in terms of the place of articulation, the manner of articulation, the oro-nasal process, the state of the glottis, and the airstream mechanism. The same organization is apparent in Pike (1943), and has been taken over by Ladefoged (1971, 1982). The division of the Place node into four major nodes has received less formal recognition but it also has a respectable ancestry in, for example, Firth (1957). As has been noted elsewhere (Halle 1988, Halle and Ladefoged 1988), the fact that there are four major nodes attached to the hyper-feature place arises because these are the four independent articulatory possibilities. The further division of these major nodes is less clear, and full of complications. For example, the actions of the lips are extremely complex in that, in addition to being closed vertically as in a normal bilabial stop, they can also be protruded and rounded. Not all combinations of rounding and protrusion are possible. The feature system needs to be able to express the fact that bilabials and labiodentals can be rounded, and bilabials (but not labiodentals) can also be protruded. One way of doing this is by regarding Rounding and Protrusion as two separate possibilities, with Protrusion being a three valued feature accounting for the distinction between bilabial and labiodental sounds, as well as for the difference between Swedish high rounded vowels.

Below the Coronal node there are two features, Anterior and Apicality. The feature Anterior allows us to differentiate among places along the roof of the mouth, and thus distinguishes dental, alveolar, and postalveolar articulations. The three way division offers an appropriate way of showing within a single feature the low level allophonic variations that occur in such words as 'eighth, eight, tray' which in many pronunciations have dental, alveolar, and postalveolar allophones of /t/. Apicality distinguishes between articulations made with the blade of the tongue, the tip of the tongue, and the underside of the blade (cacuminal retroflexes).

The Dorsal node dominates the features necessary for specifying consonants made with the body of the tongue. These features also characterize some aspects of vowels. I have retained the terms High (Low) and Front (Back) for these physiological features as shown in figure 2, although it is not at all clear that the classes of vowels defined by tongue body positions are the same as those defined by the traditional terms which correspond more to the auditory features. We should also note that the features High and Front are multivalued features, each describing an ordered set of possibilities, although they could also be regarded as complexes of binary features, if binary terminal nodes are required. With this in mind the feature Low has been listed in parentheses. The Radical node also has implications for both vowels and consonants but it is as yet unclear how these should be formalized.

As has been noted by Sagey (1986), combinations of the major place nodes within a single segment are not uncommon. Labial plus Dorsal articulations as in [kp, gb, ŋm] are the best known; Lingual plus Dorsal articulations occur in clicks; and Radical plus Dorsal articulations occur in some Caucasian fricatives (Catford 1977). Following a suggestion made by Keating (1988) I have shown the traditional term palatal as representing a complex segment with both post-alveolar coronal and front dorsal attributes. What are traditionally known as secondary articulations (labialization, palatalization, velarization, pharyngealization) can be regarded as combinations of two different places involving different manners of articulation. There are 15 possible single and multiple combinations of the four major nodes within the hyper feature Place; we do not know how many of these can or do occur.

This leads us to a brief consideration of an interesting formal problem. Recall that figure 2 is intended to be part of a descriptive statement determining the possible phonological contrasts in the languages of the world. Every sound has to be able to have some value

of each of the terminal nodes (the features). Thus each sound is either voiced or voiceless, it is either grave or it is not, etc. Note that this use of the tree structure cannot be maintained unless we allow some features to have three (or even more) values, so that, for example, the choices below Anterior consist of the set of mutually exclusive possibilities dental, alveolar and postalveolar, and those below High include the mutually exclusive possibilities high, mid, and low, for vowels and velar, uvular, and pharyngeal for consonants.

More work is obviously needed in the characterization of the set of possible manners of articulation. The hierarchical structure of the features dominated by this node is extremely hard to formalize. The first division I have suggested in figure 2 provides us with the three possibilities stop, fricative and approximant. As these items form a set of mutually exclusive possibilities, each of them can be considered as a distinct value of a single feature, here called Interrupted (a name I am not very happy with). As I noted (and then rejected) earlier (Ladefoged 1971:55): "These values form a linearly ordered set, by means of which we [can] give an explanatory account of lenition phenomena, in which stops weaken to fricatives, and a further weakening gives rise to approximants." This arrangement was rejected earlier because it did not permit fricative to be regarded as a value of a separate feature that could be added to stops for the characterization of affricates. Now, however, it seems best to regard affricates as sequences of feature specifications which can, if appropriate, occur within a single timing slot.

The next division among manner features provides the distinction between central and lateral sounds. Different values of the feature Lateral can occur with each of the values of Interrupted. Distinctions between central and laterally released stops are common (e.g. in Mayan languages); clicks are also forms of stops which utilize the central-lateral opposition. Central and lateral fricatives such as [s] and [ʃ] occur in Zulu and Welsh. Central and lateral approximants such as [ɹ] and [l] contrast in many languages, including most forms of English.

In addition to the more usual manner features I have suggested a new feature Dynamic (again, a name I am not very happy with) to account for distinctions and groupings among stops, trills, taps, and flaps. It seems likely that there is a natural class of this kind, but its internal organization is not completely clear. There is allophonic variation among stops and taps in many languages, including English. Similar variation among trills and taps occurs in languages such as Hausa; and diaphonic variation among forms of /r/ occurs in, for example, forms of Scottish English -- Ayrshire Scottish will have a trill where other forms of Lowland Scottish English have a tap or a flap. I

am not certain whether the distinction between a tap and a flap is worth pursuing. I noted earlier (Ladefoged 1971) that "A flap is ... distinguished from a tap by having one articulator strike another in passing while on its way back to its rest position, as opposed to striking immediately after leaving its rest position [in a tap]." But this may be only an incidental difference between taps and flaps, as flaps (if defined as in the quoted sentence) always have a more retracted articulation than taps. It may therefore be appropriate to consider a flap as a tap with a different place of articulation. (Again, I am still uncomfortable with this, as the dynamics of the two gestures are so very different.)

In this paper little will be said about the Oro-Nasal and the Laryngeal hyper-features. The first of these is straightforward and needs no elaboration. The second is too complex, and too specialized, to be discussed here. I suggest that both Stiffness and Glottal Aperture are multivalued features (and if binarity is considered necessary, then it can be done by the addition of extra features, as indicated in figure 2 by the terms in parenthesis). The proposed features are similar but not identical to those proposed by Halle and Stevens (1971); they reflect more nearly the parameters proposed by Stevens (1988).

The two features beneath the laryngeal node are not in themselves sufficient for characterizing all the phonologically significant states of the glottis. Just as the articulatory features High (Low), Back and Round do not of themselves explain why vowel systems are as they are, so too the features Stiffness and Glottal Aperture do not provide a direct way of explaining why most sounds are either voiced or voiceless. There has to be a separate feature accounting for these two very natural classes of sounds. As we noted above, this feature could be given either an auditory or a physiological definition. At the moment it seems that both sets of properties distinguish the same classes of sounds, although further phonological evidence may later be forthcoming to show that one or other of these definitions provides slightly better groupings. Irrespective of whether it is considered to be an auditory or a physiological feature, there is no doubt that the feature Voice is a very necessary determiner of phonological classes.

All sounds should also be considered as having some particular airstream mechanism. It might seem as if there is no need to specify the presence of the pulmonic airstream mechanism, as it is present in all sounds; even clicks and ejectives still have a positive subglottal pressure. It is, however, necessary to note that some sounds have an increase in lung power associated with them. For example, Dart (1987) has shown that Korean so-called fortis stops have a significant increase in pulmonic pressure. Both the non-pulmonic airstream mechanisms

occur in conjunction with the pulmonic mechanism (and sometimes, as in !Xóǀ, in conjunction with each other as well). The glottalic airstream mechanism has three mutually exclusive possibilities: ejective [t̥] as in Amharic, simultaneous glottal and alveolar stop [ɖ] as in my final allophones of /t/, and glottalic ingressive [ɖ̚] as in Owerri Igbo.

There are many constraints on feature combinations that are not made explicit by the paths through figure 2. Some of these are absolute constraints. For example pharyngeal nasals (to use a shorthand label for [+nasal, stop interrupted, low front dorsal] are an impossibility, as are labial and radical laterals. Some other combinations of feature values are best regarded as phonological impossibilities. For example ejective nasals (to use a shorthand label for [+stop, +nasal, ejective glottalic]) can be made, but they certainly do not appear. Yet other combinations indicate another form of overspecification in figure 2. There are combinations of values of features that can be used as ways of distinguishing the sounds of one language from those of another, which have not been observed to be used contrastively within a single language. For example there is no known contrast between a voiceless alveolar lateral fricative [ɬ] and a voiceless alveolar lateral approximant [ɭ]; but Maddieson and Emmorey (1984) have shown that some languages consistently use one of these possibilities and others the other. Distinctions such as these should be given some special status (or perhaps omitted altogether) in a theory providing an account of all possible phonologically contrastive segments. There are also the problems concerned with defining possible paths through the tree that we noted in connection with places of articulation. We can now see that there are similar problems with the airstream node, through which one may take one or more possible paths. Bearing all these points in mind, we must obviously regard figure 2 as only a limited part of a theory specifying phonological segments. It is however a first step.

The Symbols of the International Phonetic Alphabet

To conclude, we must return to the question of what should be symbolized within the International Phonetic Alphabet. The basic answer is that we should regard the traditional terms as part of shorthand labels for feature combinations. With this in mind the symbols may be taken as depicting intersections of terms which are themselves defined in terms of features. I would like to see symbols arranged in terms of several distinct charts. For example one chart might show the cardinal vowels (and perhaps some additional symbols)

in terms of the two dimensions of Height and Brightness. Another chart would show how these same (and perhaps some additional) symbols relate to the features High (Low) and Front (Back). Much of this display would be fairly similar to our present charts. The major difference would be that the symbols would be explicitly defined as being equivalent to combinations of features.

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