AN INTRODUCTION TO PARTICLE PHONOLOGY*

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Particle phonology is a radically different way of describing vowels and diphthongs--their internal structures, their interrelationships, and their evolution and change. It provides an alternative framework to the current theoretical and notational devices of generative phonology. For particular phonological processes, the standard notation fails to characterize in any enlightening way the internal structure of vowels, as well as relationships evident between particular vowels and diphthongs. The first difficulty--the nature of the internal structure of vowels--is not simply due to an inadequate set of distinctive features. Rather, the problem resides in the very notion of features as autonomous building blocks out of which segments are composed. This view contributes partially to the other difficulty--the expression of relationships between vowels and diphthongs. An additional factor to this problem comes from restrictions of the notation in regard to what may appear to the left and to the right of an arrow. The notation forces one to formulate rules whose statements often do not accord with one's conception of the nature of the processes. It seems to me that a highly-valued notational system should have the property that I have come to call 'mirroring'. If one believes that a process or change happens in a certain way, then the notation should not just describe that event but should reflect as closely as possible its manner of occurrence.

Let me illustrate what I mean by 'mirroring'. The palatalization of a consonant in the vicinity of a high front vowel is generally viewed as the assimilation onto the consonant of certain properties of the vowel. It is this relationship between the 'palatalized' aspect of the consonant and the 'palatalizing' environment of the vowel that we wish to record. Chomksy and Halle (1968: 305-308), in discussing their vowel features, note how these features describe secondary articulations in consonants. They compare their treatment of palatalization, which utilizes the features [+ high, - back], with the older feature [+ sharp]. The rules of (1) state that a consonant is palatalized before a high front vowel. Rule (1a) requires independent, unrelated features; (1b) does not.

$$\text{(1) a.}\quad C \rightarrow [+\text{ sharp}] \;/\; \_\_ \begin{bmatrix} \text{V} \\ +\text{ high} \\ -\text{ back} \end{bmatrix}$$

$$\text{b.}\quad C \rightarrow \begin{bmatrix} +\text{ high} \\ -\text{ back} \end{bmatrix} \;/\; \_\_ \begin{bmatrix} \text{V} \\ +\text{ high} \\ -\text{ back} \end{bmatrix}$$

Although both rules are sufficient for describing palatalization, the second is more revealing of the assimilation process to the extent that there is a direct mirroring between the 'palatalized' features and the 'palatalizing' environment.

For this particular example, the notation of generative phonology mirrors the nature of the process, and I believe it is fair to say that generative phonology has considered mirroring to be one of the goals of its notation. However, there are many phenomena affecting vowels and diphthongs, where the notational conventions and the associated set of distinctive features fail to reveal how the entities participate in those events. The papers in this volume, all of which deal with the historical evolution of vowels and diphthongs, illustrate some of these inadequacies of the standard notation.

This introduction to particle phonology is organized as follows. In 1., I discuss the purpose and the components of a phonological notation. In 2., I introduce the elements and descriptive devices of particle phonology and I present the particle representations of vowels and diphthongs. In 3., I look at different types of phonological processes and I show how they are accommodated within particle notation. In 4., I contrast particle phonology with the standard framework.

1. Components of a formal notation

Phonology deals with entities and events. The entities may correspond to sounds, phonemes, or even more abstract segments.[1] The events are changes--either diachronic sound correspondences, or else synchronic surface realizations of underlying representations. In all cases, something becomes something else.

A formal notation is a means for specifying entities and describing events. Although it is convenient to represent each phonological entity by a special symbol (i.e. the alphabet cum diacritic notation of traditional phonetic transcription), when looking at phonological events one finds that segments frequently participate in them in groups and, furthermore, that the same segment may belong to one group for a particular event and to another group for some other event. Therefore, in order to capture the various generalizations and cross-classifications, segments must be categorized according to sets of properties attributed to them. The distinctive features of generative phonology constitute such a set of primitive phonological elements. Other symbols (e.g. the arrow, the null symbol, parentheses) provide further descriptive devices for talking about what happens to segments. Finally, a small number of formal operations restricts the types of permitted changes: Entire segments may be inserted, deleted, or metathesized, or else one or more features of a segment may undergo a change in value. A formal notational system, then, can be characterized through three components: primitive phonological elements, descriptive devices, and formal operations.

2. The primitives of particle phonology

The primitive phonological elements of particle phonology are of two types: elementary particles and punctuators. There are three elementary particles--a, i, and u. In isolation, they correspond to the vowels [a], [i], and [u]; in combination, they represent phonological traits--aperture or openness for a, palatality or frontness for i, and labiality or rounding for u. Vowels other than [a], [i], and [u], as well as all diphthongs, are composed of combinations of particles. In typical triangular fashion, (2) depicts the segment-like and feature-like aspects of the elementary particles. Here, the particles i and u, as different manifestations of tonality, are opposed to the aperture particle a.

(2) TONALITY

i (palatality) —— u (labiality)

a (aperture)

In addition to the elementary particles, there are three punctuators: A 'plus' sign between particles signifies that the particle sets on each side of the 'plus' represent vowels belonging to separate syllables. A 'space' between particles specifies length in vowels and diphthongs. A 'half-moon' symbol beneath particles indicates nonsyllabicity.[2]

2.1. Short Vowels

The particle structures of some short vowels are presented in Table 1. (See next page.) (Traditional phonetic symbols appear in square brackets, whereas particle representations are unbracketed.) One can see how complexes of particles define the different vowels: Front vowels contain the particle i, rounded vowels have u, and nonhigh vowels exhibit a. Furthermore, vowel height is directly linked to the number of aperture particles; additional occurrences of that particle produce a 'more open' vowel. The central series of vowels requires special comment. A single occurrence of the aperture particle stands for [a] in those languages with only one central vowel. For languages with both [ʌ] and [a], it is the former that is represented by one occurrence of the aperture particle, whereas the latter would have two. Hence, the interpretation of particles (e.g. whether a represents [ʌ] or [a]) is system-dependent. The vowel [ɨ], lacking both tonality and aperture, is without elementary particles.[3]

2.2. Long Vowels

Long vowels contain extra particles and the 'space' punctuator. There are two modes of representation. First, for vowels with tonality, length may be shown by repetition of the tonality particles. Hence, front vowels will have i as their marker of length, and rounded vowels will have u. A parallelism then emerges for all vowels of a given series: Thus, [e:] is distinguished from [e] in the same way that [i:] is differentiated from [i], etc. However, for nonhigh central vowels, it is an extra occurrence of the aperture particle that marks length. An alternate mode of representation of long vowels is as a geminate sequence of two shorts. That is, there is duplication of the entire particle configuration.[4] Table 2 depicts some long vowels.

Table 1 - Short Vowels

[i]	i	[u]	u	[ʉ]	iu	[ɨ]	-
[e]	ai	[o]	au	[ɵ]	aiu	[ʌ]	a
[ɛ], [æ]	aai	[ɔ]	aau	[œ]	aaiu	[a] a, [ɑ]	aa

Table 2 - Long (Tense) Vowels

[i:]	i i	i i	[u:]	u u	u u	[ɨ:]	- -	- -
[e:]	ai i	ai ai	[o:]	au u	au au	[ʌ:]	a a	a a
[æ:]	aai i	aai aai	[ɵ:]	aiu iu	aiu aiu	[a:]	aa a	aa aa

Table 3 - Diphthongs

[ii̯]	i i̯	[uu̯]	u u̯	[ia̯]	i a̯	[i̯e]	i̯ ai
[ei̯]	ai i̯	[ou̯]	au u̯	[ea̯]	ai a̯	[i̯u]	i̯ u
[ai̯]	a i̯	[au̯]	a u̯	[ua̯]	u a̯	[i̯a]	i̯ a
[ui̯]	u i̯	[iu̯]	i u̯	[oa̯]	au a̯	[u̯e]	u̯ ai
[oi̯]	au i̯	[eu̯]	ai u̯	[aa̯]	a a̯	[u̯a]	u̯ a

Table 4 - Short Lax Vowels

[I]	ai	[U]	au	[Ü]	aiu
[E]	aai	[O]	aau	[Ö]	aaiu

2.3. Diphthongs

Complexes of particles, in their role as short monophthongal vowels, constitute unordered sets. (For convenience' sake, I list particles in alphabetical order.) For long vowels, though, a space separates the particles representing each mora. Partial ordering obtains also in the representation of diphthongs. The particle sets of the halves of a diphthong occur in their proper sequence. The 'half-moon' punctuator denotes that the sets are ordered as listed, and it also specifies the nonsyllabic component. Furthermore, diphthongs counting as more than one mora will contain the 'space' as part of their representations.[5] Some selected diphthongs are presented in Table 3.

2.4. Tense and lax vowels

For those languages that contrast long and short vowels, and where the short vowels are lax (in opposition to long tense ones), an additional specification is needed to show the more open quality of the short vowel. Hence, such vowels must contain the aperture particle in addition to whatever other particles are necessary for indicating tonality and height. Some short lax vowels are illustrated in Table 4.[6]

The particle structures of Tables 2 and 4 suggest an interpretation that will account for the doubly-marked long/tense and short/lax opposition of these vowels. In a representation such as ai i [e:], length seems to appear twice; once, as the space between particles, and again, as the second occurrence of tonality. But one can view the extra tonality particle, not so much as a redundant marker of length, but rather as an explicit indicator of tenseness. Where long/tense is opposed to short/lax, there emerges, then, a dual opposition: presence versus absence of space (interpreted as 'long' versus 'short'), and tonality particle versus aperture particle (interpreted as 'tense' versus 'lax'). This association of the tonality particle with tenseness is particularly appropriate in view of the fact that a tense vowel is considered to have 'more' tonality than its lax counterpart (Donegan 1978:63).

3. The operations of particle phonology

Particle phonology recognizes seven basic operations: Fusion, fission, mutation, cloning, droning, accretion, and decay. Fusion and fission affect the sequencing of particles, mutation involves an exchange of particles, whereas the remaining operations change the number of particles. Examples of these operations are presented in Table 5. (See next page.)

3.1. Fusion and fission

Fusion accommodates those processes where diphthongs become monophthongs. The separately occurring particles of a diphthong fuse or combine into a single complex configuration for the monophthong. One of the prime virtues of particle notation is the ease with which it relates particular diphthong/monophthong pairs. In fact, it is just such relations that provide a certain intuitive confirmation of the particle representations of the monophthongal vowels. It is not difficult to

Table 5 - Particle Operations

Fusion

[ai̯] > [e]	ai̯ > ai	Gothic, Romance, Sanskrit
[au̯] > [o]	au̯ > au	
[ae] > [ɛ]	a+ai > aai	Ewe
[ea̯] > [æ]	aia̯ > aai	Kwakiutl
[o̯a] > [ɔ]	a͜ua > aau	Rumanian
[u̯i] > [ü]	u̯i > iu	Korean
[u̯e] > [ö]	u̯ai > aiu	Korean, Old French
[eu̯] > [ö]	aiu̯ > aiu	Old French
[o̯i] > [ö]	aui̯ > aiu	Greek

Fission

[ü] > [i̯u]	iu > i̯u	Middle English
[e:] > [ei̯]	ai i > ai i̯	Old French
[o:] > [ou̯]	au u > au u̯	Old French, Icelandic
[e:] > [i̯e]	ai i > i̯ai	Icelandic
[ö:] > [öü̯]	aiu iu > aiu i͜u	Germanic
[ɪ] > [ia̯]	ai > ia̯	Soeste (Germanic)
[O] > [oa̯]	aau > aua̯	Soeste

Mutation

[ei̯] > [oi̯]	aii̯ > aui̯	Old French
[ou̯] > [eu̯]	auu̯ > aiu̯	
[ii̯] > [ui̯]	i i̯ > u i̯	Soeste, Old West Scandinavian
[uu̯] > [iu̯]	u u̯ > i u̯	Soeste

Table 5 - (Continued, 2)

Cloning

[u] > [ü] / __ [i]	u > i̲u / __ i	Germanic
[o] > [ö] / __ [i]	au > ai̲u / __ i	
[i] > [ü] / __ [u]	i > iu̲ / __ u	
[i] > [e] / __ [a]	i > a̲i / __ a	Early Germanic
[u] > [o] / __ [a]	u > a̲u / __ a	
[e] > [e̯a] / __ [a]	ai > a̲i̯a̲ / __ a	Rumanian
[o] > [o̯a] / __ [a]	au > a̲u̯a̲ / __ a	
[ai̯] > [ei̯]	a i̯ > ai̲ i̯	Old High German
[au̯] > [ou̯]	a u̯ > au̲ u̯	

Droning

[æ] > [e] / __ [i]	a̲ai > ai / __ i	Old English
[e:] > [i:]	a̲i i > i i	Early Modern English
[o:] > [u:]	a̲u u > u u	
[ɛ:] > [e:]	a̲ai i > ai i	
[ɔ:] > [o:]	a̲au u > au u	

Accretion

[u] > [ü]	u > i̲u	Old French
[i] > [I]	i > a̲i	Vulgar Latin
[u] > [U]	u > a̲u	
[ii̯] > [ei̯]	i i̯ > a̲i i̯	Early Modern English
[uu̯] > [ou̯]	u u̯ > a̲u u̯	
[ii] > [ei]	i i > a̲i i	Scanian (Swedish)
[ee] > [ɛe]	ai ai > a̲ai ai	
[ɛɛ] > [æɛ]	aai aai > a̲aai aai	

Table 5 - (Continued, 3)

<u>Decay</u>

[ü] > [i]	iu̯ > i	Old West Scandinavian, Greek, English
[ü] > [u]	i̯u > u	
[e] > [a]	ai̯ > a	Sanskrit
[o] > [a]	au̯ > a	Sanskrit
[e] > [i]	a̯i > i	Luiseño
[o] > [u]	a̯u > u	
[e] > [i]	a̯i > i	Russian
[o] > [a]	au̯ > a	

find instances where diphthongs or sequences of vowels have fused into single vowels whose particle representations agree with the sequential entities. For example, in a multitude of languages, [ai̯] and [au̯] have become [e] and [o], respectively. This change has occurred in Gothic and throughout Romance. Sanskrit provides another well-known case, for in that language the diphthongs continue to alternate with the corresponding monophthongs. Fusion also provides motivation for the multiple-aperture representation of the lower vowels. In Ewe, an African language, [ê] occurs as a frequent contraction of [a] and [e]--for example, [na e] 'to him' becomes [nê]. In Kwakiutl (SPA 1979:730), one of the sources of [ae] is the diphthong [ea̯]. In some Rumanian dialects (Nandris 1963:86), the diphthong [o̯a] has fused to [ɔ], These examples represent fusions of aperture and tonality. There are also monophthongizations of just tonality. In Korean (SPA 1979:380), [u̯i] and [ü] occur in free variation; so do [u̯e] and [ö]. The diphthongs [u̯e] and [eu̯] of old French have both become [ö] in the modern language, whereas in some of the dialects of ancient Greek it was [oi̯] that evolved to [ö]. In particle notation, diphthong/monophthong pairings are nothing other than the temporal sequencing of particles--linear versus simultaneous realization, and diphthongs that exhibit different sequences of the same combinations of particles must be linked to the same monophthong. (Note, in particular, the last three examples.)

Fission is the opposite of fusion. It handles the diphthongization of monophthongs. The complex particle configuration of a monophthong is split up to become a sequence of particles for the diphthong. This process is evident in the middle English borrowing of French [ü]. The French monophthong is rendered as [i̯u] in English. As another example, consider the diphthongization of long vowels. In old French, [e:] and [o:] underwent diphthongization to [ei̯] and [ou̯]. In Icelandic, [o:] too changed to [ou̯], but [e:] became instead the rising diphthong [i̯e]; only the sequencing has changed. In Germanic, [ö:] becomes a diphthong with a front rounded glide. In these examples of fission, one sees how a long vowel splits up into that vowel and a glide. The tonality particles that originally were part of the length representations of the long vowels become the sources of the homorganic glides of the diphthongs. Fission may also affect the aperture particle. In the Soeste dialect of low German (Grundt 1975:55), lax vowels diphthongized into vowels of higher quality and following downglide: [I] > [ia̯], [E] > [ea̯], [U] > [ua̯], and [O] > [oa̯]. The aperture particle for laxness in the monophthongs has been serialized as the downglide of the diphthongs.

3.2. Mutation

Mutation interchanges the two tonality particles: i is replaced by u and, conversely, u is replaced by i. Mutation is the particle analog of tonal dissimilation. Romance and Germanic provide some examples. As already noted, old French had acquired the diphthongs [ei̯] and [ou̯]. Subsequently, [ei̯] changed to [oi̯], and [ou̯] became [eu̯]. In the Soeste dialect (Grundt 1975:55), the long high vowels diphthongized and their first elements also switched tonality: [i:] > [ii̯] > [ui̯] and [u:] > [uu̯] > [iu̯]. Old West Scandinavian [i:] and [ü:] merged to [i:], which then became the diphthong [ui̯] in modern Faroese (Andersen 1972:22).[7] As a consequence of mutation, there is greater tonal separation between the syllabic and nonsyllabic halves of a diphthong.

3.3. Cloning and droning

Cloning and droning affect the number of particles of a configuration. Both are the particle analogs of assimilation. In one common type of cloning, a particle from one syllable is copied into the vowel of another syllable. Germanic umlaut is an obvious example. The rounded vowels [u] and [o], when followed in the next syllable by [i], were fronted to [ü] and [ö], respectively. The particle i from the umlauting environment has been copied into the preceding vowel. In the less common, but nonetheless similar, labial umlaut, a labial particle is copied into the vowel of the previous syllable. There is also cloning of the aperture particle. In early Germanic, the high vowels [i] and [u] were lowered to [e] and [o], respectively, when followed by [e], [o], or [a], all of which contain the particle a. In Rumanian, [e] and [o] have been 'broken' into the diphthongs [e̯a] and [o̯a]. The breaking took place when these vowels were followed by [e], [ʌ̂], or [a]. An aperture particle from the second vowel has been cloned and has become the nucleus of the 'broken' diphthong. Cloning can take place also between the two parts of a diphthong. In the development of old High German, [ai̯] became [ei̯], and [au̯] became [ou̯]. The tonality particle of the glide has been cloned into the nucleus of the diphthong.

Whereas the vowels [u], [o], and [a] of old English were umlauted to [ü], [ö], and [ae], respectively, original [ae] in an umlaut environment was raised to [e].[8] The fronting of back vowels has been described as the cloning of the particle i from the second vowel into the target, so that the palatal particle is added to vowels originally not possessing it. However [ae] already contains the palatal particle. Hence, the only way that this vowel can become more like a following [i] is through an increase in height, or, equivalently, through a loss of aperture, and this is precisely what occurs. For the palatalization (umlaut) process, then, vowels that lack the palatal particle will acquire one, whereas those already possessing one will lose an opposing particle. The latter phenomenon constitutes droning.[9] Part of the Great Vowel Shift (GVS) of English also exempflifies droning. Long mid vowels became highs, and lower mid vowels were raised to mids. In particle notation, an upward shift of this type is easy to characterize: It is loss of an aperture particle.

3.4. Accretion and decay

Accretion and decay change the number of particles in nonassimilatory environments. Accretion is the spontaneous addition of a particle. Vulgar Latin [u] became [ü] everywhere in French. The particle i has been added. At an early stage in the history of Latin, there were contrasting pairs of long and short vowels of the same quality. Subsequently, short [i], [e], [u], and [o] became lax--that is, they acquired the particle a. We noted that in the first stage of the GVS, the mid vowels and lower mids were raised one degree. The high vowels instead diphthongized and were lowered one step: [ii̯] became [ei̯], and [uu̯] became [ou̯]. Here too there is addition of an aperture particle. A more dramatic example of lowering is seen in the Scanian dialect of

Swedish (Bruce 1970). Long vowels, which behave as two shorts, diphthongize: The first half of the long vowel moves down one step. This development for the front unrounded vowels is as follows: [ii] > [ei], [ee] > [êe], and [êê] > [aeê]. In particle notation, downward vowel shifts represent the acquisition of aperture particles.

Decay is simplification of a complex particle configuration: One or more of the component particles are lost. Most neutralizations provide examples of decay. In the merger of old West Scandinavian [i:] and [ü:], the latter lost its labial particles. In Greek [ü] also merged with [i], and the same change occurred in the history of English with the loss of umlauted vowels. Although unrounding, or loss of the particle *u*, seems to be the favored way for front rounded vowels to be simplified, it is also possible for them to give up palatality, or the particle *i*. This version of decay causes [ü] to merge with [u]. The dual tonality structure of front rounded vowels accounts for both avenues of decay. Indo-European had the vowel qualities [i], [e], [a], [o], and [u], which occurred both long and short. In Sanskrit [e] and [o], both long and short, merged with [a]: The mid vowels lost their tonality particles. Luiseño, an Amerindian language of Arizona (Bright 1965: 343), has also five vowels. In unstressed syllables, [e] and [o] merge with [i] and [u], respectively: The mid vowels lose their aperture particles. Russian exemplifies a mixed system, where, in unstressed positions, [e] has merged with [i], a loss of aperture, but [o] has merged with [a], a loss of tonality.

3.5. *An example of a chain reaction*

I provide in (3) an example of the interaction of several particle operations. Consider the sequence of developments from vulgar Latin [o:] and [e:] (lengthened in stressed syllables) to modern French [ö] and [u̯a], respectively--e.g. Lt. *flōr*, *mē*; Fr. *fleur*, *moi*.

(3) [o:] > [ou̯] > [eu̯] > [ö]

[e:] > [ei̯] > [oi̯] > [u̯e] > [u̯a]

	Fiss	Mut	Fus	Fiss	Decay
au u >	auu̯ >	aiu̯ >	aiu		
ai i >	aii̯ >	aui̯ >		u̯ai >	u̯a

We have already noted the first two stages: [o:] and [e:] diphthongized to [ou̯] and [ei̯], and the nuclei of the diphthongs then underwent dissimilation, becoming [eu̯] and [oi̯], respectively. The former then monophthongized to [ö]. The other diphthong, [oi̯], had a very different development: It changed to [u̯e]. (French eliminated its falling diphthongs either through monophthongization or through conversion to rising diphthongs.) Finally, [u̯e] became [u̯a].

Observe the particle analysis of these changes. The original vulgar Latin long vowels undergo fission. Next, the nuclei of the diphthongs are subject to mutation. For [eu̯], there is then fusion to [ö]. The progression from [o:] to [ö] can be characterized as an exchange of tonality particles (mutation), sandwiched between changes in the sequencing of particles (fission and fusion), but the number of particles remains constant. Consider now the development of the diphthong aui̯ [oi̯]. Nonsyllabicity moves into the first half of the diphthong and becomes attached to the labial particle; the aperture particle then gravitates into the nucleus, yielding u̯ai [u̯e]. Once again, there is nothing more than a resequencing of the existing particles. Finally, simplification or decay takes place in the nucleus, the first instance of loss of a particle. I suggest, as an exercise, that the reader recast these changes in the standard notation of generative phonology and compare that restatement to the particle notation.

3.6. Three laws of particle phonology

There are situations where particle representations require adjustments. These modifications are due to some general properties governing the structure of vowel systems.

3.6.1. The law of mora conservation

In languages with both long and short vowels, diphthongs generally behave like long vowels. Mora conservation requires that mora count be preserved during fusion and fission (Vennemann 1972:869). In Sanskrit, the diphthongs [ai̯] and [au̯] constituted two morae. The resulting fusion in that language yielded [e:] and [o:], respectively, and not short vowels (Allen 1962:31). With just two particles there is no way that a+i or a+u can directly fuse into long mid tonality vowels. In order to respect mora conservation, there occurs *cross-cloning*: Each particle is copied into the other mora. In this way, a+i and a+u, upon fusion, will yield ai ai and au au, respectively. Notice, though, that in a language, such as Spanish, that does not contrast long and short vowels, a fusion of a+i or a+u will produce ai or au directly.

3.6.2. The law of diphthongal differentiation

Diphthongal differentiation requires that the syllabic and nonsyllabic parts of a diphthong differ from each other either in height or in tonality (i.e. the two halves of a diphthong may not be identical), if that diphthong is to contrast with the corresponding long vowel. What this means is that [ii̯] and [i:], for example, would never be contrastive in the same language, but [ei̯] and [e:] very well could be. Now the diphthongs [ii̯], [uu̯], and [aa̯] do arise in the course of change. Because they are structurally equivalent to the corresponding long vowels, either they will merge with those vowels, or else, if they are to remain diphthongs, the language must modify them in some way.

3.6.3. The law of maximum aperture

In the discussion of central vowels, it was noted that [a] must be represented as aa if [^] is present in the vowel pattern. The representation of [a] will depend also on the number of tonality vowels. Maximum aperture requires that [a] not have fewer aperture particles than the lowest tonality vowels. This adjustment accommodates the interaction of [a] with these vowels. In Sanskrit, with a three-vowel system, the fusion of [a] and [i] produced [e:]. A similar change happened in the history of Spanish, with its five-vowel system. However, in vulgar Latin, which had developed a seven-vowel pattern of the type [i], [e], [ê], [a], [ɔ], [o], and [u], the fusion of [a] and [i] yielded [ê]. In old English, there were also three front unrounded vowels. In the umlaut process, [a:] was fronted to [ae:]. In vulgar Latin and in old English, because the lowest front vowel has two occurrences of the aperture particle, so must [a].

As another example of the law of maximum aperture, let us see how it interacts with vowel harmony in Turkish. Turkish has eight vowels, as represented in (4).

(4)	[i]	[u]	[ü]	[ɨ]	i	u	iu	-
	[e]	[o]	[ö]	[a]	ai	au	aiu	a

Because the lowest tonality vowels are mid (i.e. have one aperture particle), [a] too is represented by a single occurrence of the aperture particle. Furthermore, it is the aperture particle that minimally distinguishes [a] from the particleless [ɨ]. In the particle representations of the Turkish vowels, all high vowels lack the aperture particle, whereas all nonhigh vowels contain exactly one occurrence of it. This structure is crucial for the operation of vowel harmony. In (5) are shown the variants of suffix vowels that occur after preceding vowels. Note that there are four variants where the suffix contains a high vowel, but only two where there is a nonhigh vowel.

(5)	Preceding V	Suffix V	Preceding V	Suffix V
	[i], [e]	[i]	[i], [e]	[e]
	[u], [o]	[u]	[u], [o]	[a]
	[ü], [ö]	[ü]	[ü], [ö]	[e]
	[ɨ], [a]	[ɨ]	[ɨ], [a]	[a]

In Turkish, vowels harmonize for tonality. Let us assume that the underlying forms of suffixal vowels are without tonality, and that the purpose of vowel harmony is to add tonality to these vowels. In underlying representations, then, a high suffixal vowel will be represented by the particleless [ɨ], whereas a nonhigh one will be represented as [a]. The vowel harmony process functions as follows: (1) The tonality particle(s) from a preceding vowel will be cloned (copied) into a high suffixal vowel. (2) Only the palatal particle from a preceding vowel will be cloned into a nonhigh suffixal vowel. In the case of underlying particleless [ɨ], it will acquire palatality (becoming [i]), labiality (becoming [u]), or both palatality and labiality (becoming [ü]) after front unrounded, back rounded, and front rounded vowels, respectively; where the preceding vowel is central, there is no tonality to be cloned and, consequently, underlying [ɨ] will surface as such. In the case of underlying [a], it will acquire palatality (becoming [e]) after any front vowel; because it never acquires labiality, [a] will surface as such after any nonfront vowel. Notice that in particle notation, the addition of the palatal particle to [a] is sufficient to convert it to [e]. We do not need to state as part of the vowel harmony rule that with the addition of tonality a low vowel is raised to mid height.

4. A comparison of features and particles

The most salient difference between the standard framework and particle phonology is in the choice of primitive phonological elements. Let us contrast some of the properties of distinctive features and of elementary particles.

Distinctive features are atomistic, inclusive, unitary, and autonomous. Segments are composed of features; segments are specified for all relevant features; each feature occurs exactly once; and the phonologic interpretation of features is (by and large) language-independent.

Elementary particles are compositional, additive, multiple, and dependent. Complex vowels are composed of simpler ones; vowels are specified only for those components present; particles may occur multiply; and because of their different functions, the interpretation of particles is language-dependent.

Let us look at each of these characteristics.

4.1. Atomistic vs. compositional

The standard framework sharply differentiates between segments and features. The former are composed of the latter. In particle phonology, the entity and the property are entwined. Particles represent individual vowels as well as traits of vowels. Color provides a useful analogy. Red, blue, and yellow are the primary colors of the artist's palette. These three exist as independent colors, and combinations of them produce all other colors. It is the dual physiognomy of particles that allows a simple account of alternations between diphthongs and monophthongs. In the fusion of [a$\hat{i}$] to [e], for example, the sequential particles of the diphthong are functioning as independent segments, whereas in the resulting monophthong the same two particles function as properties of the vowel. With features, on the other hand, there is no way that the two sets of features composing the halves of a diphthong can fuse into a monophthong, simply because one or more features of the sets will have contradictory values (i.e. will be specified as + in one of the segments and as - in the other).

4.2. Inclusive vs. additive

In the feature framework, segments require a specification (i.e. a + or a - value) for each of the features. In particle phonology, vowels are specified only for those components that are present. The additive nature of particles provides a built-in 'markedness' system: Number of particles correlates to degree of complexity. This characteristic also accounts for a fundamental property of diphthong/monophthong pairs: Each half of the diphthong is phonologically simpler than the corresponding monophthong.

4.3. Unitary vs. multiple

Each distinctive feature occurs at most once in the specification of a segment. Elementary particles may occur multiply. First of all, because there are fewer particles than features, particles must occur more than once if only to cover all of the types of vowel contrasts. This property is evident in the treatment of both vowel height and vowel length. Multiple occurrences of aperture accommodate very elegantly those vowel shifts where vowels of differing height move stepwise up or down the height scale. Multiple occurrences of tonality make it possible to characterize relationships between long vowels and diphthongs.

4.4. Autonomous vs. dependent

The distinctive features are autonomous. Because features have fairly exact phonetic correlates, each feature plays a precise role in defining a segment. The most important property of particles is their capacity to perform different functions. The tonality particles i and u correspond to high vowels, when uncombined; they function as upglides, when nonsyllabic; they indicate frontness and rounding, respectively, when part of a complex configuration; and they denote length and/or tenseness, when in combination with tonality vowels. The particle a corresponds to a central vowel, when uncombined; it functions as a downglide, when nonsyllabic; it indicates lowered height, when part of a complex configuration; it marks length for central vowels; and it denotes laxness for those vowels opposed to tense ones. But in neither case is it a question of arbitrary associations. In one instance, the various properties are manifestations of a generalized tonality, and in the other, of aperture. However, the particular interpretation of a particle--for example, whether the aperture particle denotes lowered height or laxness--will depend on the language system and other elements that are present. The nonautonomous character of particle representation is by no means a liability. It accounts, for example, for such phenomena as the association of lax vowels with vowels of the next lower height (Schane 1984), and relations between tenseness and palatality/labiality (Schane, forthcoming). These various relationships cannot be expressed with the distinctive features. The inadequacies stem from a too-close correlation with phonetic substance. Particles, by reducing vowel properties to expressions of tonality and aperture, classify vowels in a highly abstract manner. It is this greater degree of abstraction that lends a new perspective to the study of vowels and their evolution.

FOOTNOTES

* This introduction to particle phonology, with minor changes, is a composite of sections from Schane (forthcoming).

[1] Phonology deals, of course, with entities other than segments (e.g. prosodic phenomena). Particle phonology is a theory about segmental entities and, in particular, vowels.

[2] The 'plus' corresponds to the SPE feature [+ syllabic], the 'space' to [+ long], and the 'half-moon' to [- syllabic]. The three elementary

particles, on the other hand, accommodate various values of the features [high], [low], [back], [round], and [tense].

[3] To say that [ɨ] is particleless is not to suggest that it is an empty vowel. It still maintains vocalicness, a trait it shares with all other vowels. What is unique about [ɨ] is its lack of elementary particles.

[4] Traditionally, there are two ways to represent long vowels: either as a single segment specified as long, or else as a sequence of two identical short segments. Both representations are needed for phonological description (Kenstowicz 1970, Pyle 1970). One approach treats length as a feature, the other as an independent segment. The notational variance of [e:] and [ee], for example, is reflected as ai i and ai ai in particle phonology. Now in the standard notation, there is no inherent relationship between an independent feature [+ long] and an entire duplicated segment. In particle phonology, one can view the abbreviated representation of length as a 'factored' version of the full representation, where, for example, a(i i) is equivalent to ai ai, except that the parentheses can be omitted.

[5] Particle phonology can differentiate the following: an 'overshort' diphthong such as [e͡i] ai i̯, that counts as one mora; a 'normal' diphthong of the type [ei̯] ai i, that counts as two morae; and an 'overlong' diphthong such as [e:i̯] ai i i̯, that counts as three morae.

[6] The particle configurations of lax vowels overlap with some of the vowels of Table 1. Thus, [I] coincides with [e], [U] with [o], etc. Recall, from the discussion of [a], that the interpretation of particles depends on the network of contrasts in a particular vowel system.

[7] Old West Scandinavian [u:] has become [ʉu̯] in Faroese (where [ʉ] represents a front rounded vowel). I would maintain that [u:] first became [uu̯], then [iu̯] via mutation (exactly analogous to [i:] > [ii̯] > [ui̯]); subsequently, the [i] of [iu̯] was labialized by the following glide. My interpretation of the OWS data differs dramatically from that of Andersen (1972), who, in the context of his theory of diphthongization, claims that [i:] first became *[ɨ:], which then diphthongized to [ui̯], whereas [u:] became *[ʉ:], then [ʉu̯]. Both Andersen's and my scenarios are examples of the way that theories lead to interpretations of data.

[8] In the umlaut and raising of old English, [a] was fronted to [ae], then subsequently raised to [e]. Its long partner [a:] was only fronted to [ae:]. Umlauted [ö] and [ö:], derived from [o] and [o:], were soon unrounded to [e] and [e:].

[9] Droning is the elimination of a superfluous particle. The term has an apiarian origin. The male bee, when no longer needed, is ejected from the hive.

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