A GENERATIVE PHONOLOGY OF CLASSICAL ATTIC GREEK

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ABSTRACT

A GENERATIVE PHONOLOGY
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By

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Classical languages have received much attention from linguists for many centuries. Most of this work has been done within traditional frameworks. The following thesis is an attempt to describe the phonological system of classical Attic Greek in generative terms.

Some attention is given to the many problems involved in doing phonological research on a dead language. The introduction deals with the problems of orthography and language change. The resolution of difficulties in these areas is drawn from both ancient and modern sources.

The bulk of the research involves a description of morphophonemics at inflectional word boundaries in terms of a set of rewrite rules. In gneral these rules conform to the type discussed in The Sound Pattern of English (Chomsky, Halle 1967).

The problem of "length" is dealt with as it applies specifically to Greek. This discussion points to certain difficulties found in treating "syllable" and "mora" within the generative framework.

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To my Creator and the encouragement of His Word. "Study to show thyself approved unto God, a workman that needeth not to be ashamed, rightly dividing the word of truth." (II Timothy 2:15)

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INTRODUCTION

The purpose of this thesis is to provide a generative description of the phonology of the Greek spoken in Athens in the fourth century before Christ. This particular dialect is probably the most fully "alive" of all the "dead" languages. It has received the attention of scholars beginning with Dionysius of Halicarnassus and the Alexandrians up until the present. It is then natural that it should be treated in terms of a modern linguistic framework.

The reason for the selection of Attic rather than Doric or Ionic or any other Greek dialect is almost as much romantic as it is practical. Attic is the language of Plato and the great tragic poets. It is the vehicle of a truly monumental literary culture. This has led to two important results--the survival of a larger corpus in Attic than in any other Greek dialect and the greater attention paid to this dialect by scholars. It is not surprising then, that when scholars refer to "Classical Greek" they invariably mean "Attic Greek." The other dialects are rarely discussed without mention of the points in which they differ from this standard.

1.1 Orthography

The greatest problems involved in arriving at a phonology of Attic are found in connection with the orthography. For centuries, scholars have been curious about the actual sounds of ancient Greek. In spite of the seeming sureness exhibited by some scholars on this topic, there are still many areas where they can only be speculative. In addition, the orthography in many ways reflects the notion of traditional phonemic contrast, so that the details which lie below the traditional phonemic level are very difficult to determine.

The consonants present the fewest problems.[1] Most scholars tend to agree that Greek contained three series of stops (voiced, voiceless, and voiceless aspirated) in three positions (bilabial, alveolar, and velar). There were three corresponding nasals, but structural descriptions specify that the velar nasal was only allophonic. There were two liquids (/r/ and /l/). Also, there existed a little understood feature of aspiration (spiritus asper or "rough breathing"). Greek was notable among Indo-European languages in that it contained no affricates and only one, possibly two, continuant consonants (i.e. /s/ and zeta). Zeta has continually presented insurmountable problems. Symmetry demands that it should be a voiced counterpart of sigma (/s/), but almost definitely it was not that until at least after the first century A.D. It is occasionally formed from morphophonemic combination of /s/ and /d/ in either order. Zeta carried a low functional load and rarely participated in

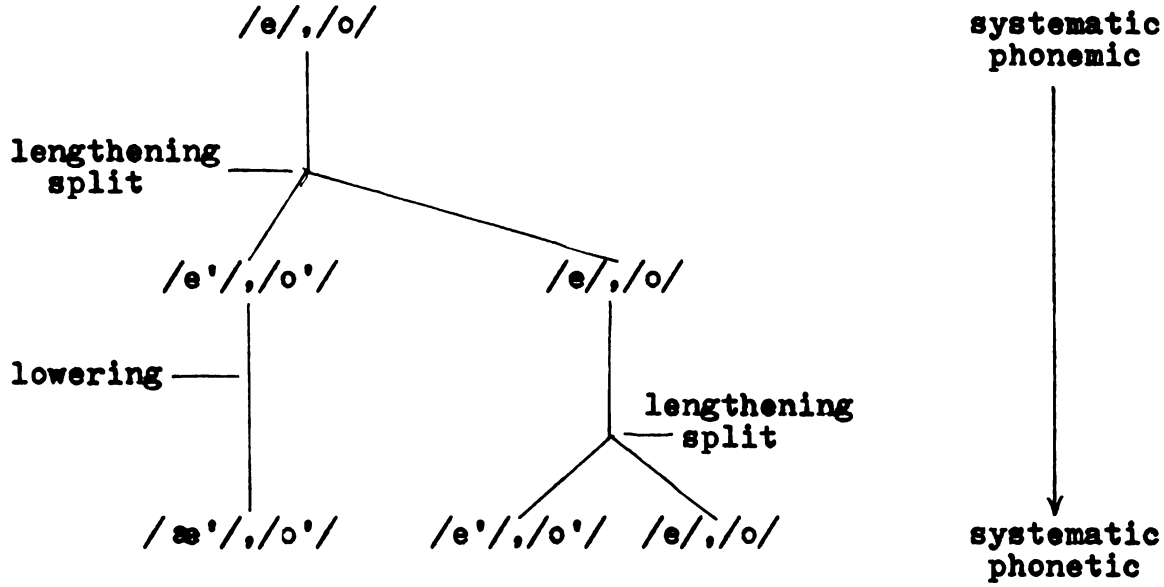
morphophonemic alternations. The most comprehensive work to date on this problem is that of Bailey in The Papers of the Fourth Regional Meeting of the Chicago Linguistic Society.

In 403 B.C. Athens adopted the Ionic alphabet. In general there was a one-to-one correspondence between letters and structurally contrastive phonemes, but this did not always hold true. There were two digraphs (ksi and psi) which stood for consonant clusters (/ks/ and /ps/ respectively). Because orthographies are cultural artifacts, anomalies such as ksi and psi are to be expected. For the most part the Ionic alphabet was an accurate and convenient device for transcribing the Attic consonants. This, however, can not be said of the vowels.

Greek has seven orthographic vowels and a set of diphthongs. Systematically it has five vowel phonemes. However, the orthography does not reflect the systematic phonemes, but only the obvious phonetic differences. Many major problems arise from vocalic "length." Greek had lengthened counterparts for all vowels, but in the mid region these lengthened vowels were lowered. Thus they were still long but also differed in height. Subsequently the original mid-vowels again produced lengthened counterparts. Lacking proper orthographic symbols, the Greeks represented these new long mid-vowels as diphthongs (so called "spurious diphthongs").

The derivational steps illustrated for the mid-vowels in the chart below roughly reflect the historical development of these vowels. This lends further support to the idea that

diachronic investigations can give insight into synchronic phenomena. Synchronic rule ordering does not always reflect the order of historical changes, but this is often the case.



There is little reason to think that the short vowels differed appreciably in quality from their long counterparts. However, eta and omega (/æ'/ and /ɔ'/) have no non-long equivalents. At one time they evidently had the same sound as /e'/ and /o'/ respectively. Compensatory lengthening is a very important process in Greek, and /e'/ and /o'/ are produced from /e/ and /o/ by certain early lengthening rules. Then these long vowels are lowered to become /æ'/ and /ɔ'/ (represented in fourth century orthography by eta and omega). Later lengthening rules produce the spurious diphthongs (/e'/ and /o'/) from /e/ and /o/.

Short /u/ almost certainly became a front rounded vowel some time before the Byzantine period. Often this change has

been dated as before or during the Attic period; however, little real evidence exists and the point is not crucial. Long /u'/ was probably unchanged.

The most striking sound change occurred in Attic in the fifth century B.C. when long alpha /a'/ changed to eta /æ'/. The change was uniform and complete in Ionic, but in Attic exceptions occurred after rho, epsilon, and iota (/r/, /e/, and /i/). Buck claims (Buck 1928,p.38) that in Attic two changes were occurring. First of all, long alpha was changing to a sound not quite equivalent to the sound of eta. Meanwhile, a competing innovation was returning these new sounds to long alpha when they occurred after rho, epsilon, or iota. After both changes had run their course the new sound eventually merged with the sound of eta. There is little, if any, historical evidence to support this claim. Even if it is true diachronically, the situation is best described synchronically with an exception rule in which /r/,/e/, and /i/ are the exceptional environments. See 2.10, rule (10).

All of the non-high vowels could form diphthongs with high vowels as second elements. In some cases these were purely orthographic and did not represent true diphthongs, but rather long mid vowels. These "spurious diphthongs" had originally been true diphthongs which underwent monophthongization. Later compensatory lengthening produced long mid vowels and the same orthographic diphthong was used to represent these (Buck 1933,pp.91-2).

The long vowels formed particularly unstable diphthongs

in which there was a tendency for the second vowel to be dropped, or for the first element to be shortened to form a diphthong of the usual variety (Buck 1933, pp.90-1).

1.2 Traditional Treatments

Traditional treatments of this topic have by no means been inadequate in the light of the evidence available. As in all areas some descriptions have been good and some bad. The notion of "natural class" was used extensively even in literature antedating the Prague School.

Goodwin's work (1879) is one of the best examples of a traditional description of Greek phonology. It is complete and detailed, but tends to overlook some generalizations that are more or less obvious within a generative framework. For example, his treatment of the consonants divides stops by position into labial, palatal, and lingual classes and into smooth, middle, and rough orders corresponding to unaspirated voiceless, unaspirated voiced, and voiceless aspirated respectively. Thus with these classes it is rather simple to write rules describing assimilation of voicing, aspiration, or position. Each of these class names is in effect a label for a particular feature or bundle of features.

Descriptions of vowels tend to be much less systematic. Even the very best treatments do no more than list the possible contractions that occur at word and morpheme boundaries. Occasionally other vowel phenomena, such as compensatory lengthening, are amenable to more general rules; but traditional

treatments of even compensatory lengthening have not been able to distinguish between historically long vowels (eta and omega) and the truly long mid vowels (spurious diphthongs). These changes can best be handled only by a set of rules in which ordering plays a role.

1.3 Alphabet with Phonetic equivalents

Greek letter	name	probable phonetic equivalent
α	alpha	a,a'
β	beta	b
γ	gamma	g
δ	delta	d
ε	epsilon	e
ζ	zeta	(uncertain)
η	eta	æ'
θ	theta	t^h
ι	iota	i,i'
κ	kappa	k
λ	lambda	l
μ	mu	m
ν	nu	n
ξ	ksi	ks
ο	omicron	o
π	pi	p
ρ	rho	r
σ,ς	sigma	s
τ	tau	t
υ	upsilon	u,u'
φ	phi	p^h
χ	chi	k^h
ψ	psi	ps
ω	omega	ɔ'
ει	"spurious diphthong"	e'
ου	" "	o'

1.4 Feature Specifications for Greek Systematic Phonemes

	p	t	k	b	d	g	p^h	t^h	k^h	l	r	m	n	s	h	i	e	æ	a	u	o	ɔ
SONORANT	–	–	–	+	+	+	–	–	–	+	+	+	+	–	–	+	+	+	+	+	+	+
VOCALIC	–	–	–	–	–	–	–	–	–	+	+	–	–	–	–	+	+	+	+	+	+	+
CONSONANTAL	+	+	+	+	+	+	+	+	+	+	+	+	+	+	–	–	–	–	–	–	–	–
CORONAL	–	+	–	–	+	–	–	+	–	+	+	–	+	+	–	–	–	–	–	–	–	–
ANTERIOR	+	+	–	–	+	–	+	+	–	+	+	+	+	+	–	–	–	–	–	–	–	–
HIGH	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–	+	–	–
LOW	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	+	+	–	–	+
BACK	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	+	+	+
ROUND	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+	+	+
•DISTRIBUTED	+	+	+	+	+	+	+	+	+			+	+									
NASAL	–	–	–	–	–	–	–	–	–	–	–	+	+	–	–	–	–	–	–	–	–	–
LATERAL	–	–	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–
CONTINUANT	–	–	–	–	–	–	–	–	–	+	+	–	–	+	+	+	+	+	+	+	+	+
ABRUPT PRI-MARY RELEASE	+	+	+	+	+	+	+	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–
•TENSE	+	+	+	–	–	–	+	+	+	–	–	–	–	+								
VOICED	–	–	–	+	+	+	–	–	–	+	+	+	+	–	–	+	+	+	+	+	+	+
STRIDENT	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–
COVERED	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
GLOTTAL CONST.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
SEC. RELEASE	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
VELAR. SUCTION	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
IMPLOSION	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
EJECTIVE	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
HEIGHT. SUBGL. PRESSURE	–	–	–	–	–	–	+	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–

•Specifications omitted because of indeterminability in this study.

STATEMENT OF RULES

Most morphophonemic changes in Greek occur at inflectional morpheme boundaries. The few that occur with prefixes are relatively less important because they affect a very restricted class of morphemes.

There are two parallel sets of surface vowels--short and long.

SHORT		LONG	
i	u	i'	u'
e	o	e'	o'
a		ae'	ɔ'
		a'	

Since there are more long vowels than short vowels it would be reasonable to look for data indicating that two of the long vowels are derived from other sources. Such data is hinted at in Greek but is by no means clear. An interesting phenomenon occurs in the nominative singular of some third declension nouns. The usual nominative singular ending for such nouns is /-s/. However, in some words this ending is not present, and the stem vowel is different from that of the oblique forms:

	oblique form	expected nominative	occurring nominative
lion	leontos	leons	leɔ'n
shepherd	poimenós	poimens	poimæe'n
leader	hæ'gemonos	hæ'gemons	hæ'gemɔ'n
divinity	daimonos	daimons	daimɔ'n
orator	hræ'toros	hræe'tors	hræe'tɔ'r

The following rule is observationally adequate for describing the above phenomena:

(1) $\begin{bmatrix}+voc\\-cons\\-high\\-low\end{bmatrix}\begin{bmatrix}+son\\+cons\end{bmatrix}$ [+FB] [+strid] [+WB] $\begin{bmatrix}+low\\+long\end{bmatrix}$

1 2 3 4 5 ⟹ 1 2 3 ø 5

Not only does loss with compensatory lengthening occur, but there is also a change of quality in the lengthened vowel. Such a change in quality is unusual and unexpected. A better explanation for this data would split the rule in two--into a lengthening rule, and a rule which lowers the long mid vowels. Thus:

(2) $\begin{bmatrix}+voc\\-cons\\-high\\-low\end{bmatrix}\begin{bmatrix}+son\\+cons\end{bmatrix}$ [+FB] [+strid] [+WB]

1 2 3 4 5 ⟹ 1123ø5

(3) $[-low] \rightarrow [+low] \;/\; \begin{bmatrix}\underline{\quad}\\+voc\\-cons\\-high\\+long\end{bmatrix}$

Rule (3) must be considered intuitive. There is no data which directly justifies it. However, it is consistent with the rest of the phonology to say that the surface long low vowels /æ'/ and /ɔ'/ are from underlying long mid vowels /e'/ and /o'/ by rule (3).

All of the surface long mid vowels are produced in the following ways:

(1) from /e/ and /o/ by later compensatory lengthening rules.

(2) by vowel contractions of /e//e/ and /o//o/ at boundaries.

(3) by monophthongization of /ei/ and /ou/.

A major descriptive problem here is whether long vowels should be represented in the phonological rules as geminate clusters as in rule (2) or as a feature of length as in rule (3). No feature of length is presented as a universal feature in The Sound Pattern of English. However, other research has seen fit to use such a feature (vid. Kuroda, 1967).[2] The following criteria will be used in judging between these two alternatives:

(1) Which alternative offers the most economical description?

(2) Is a proposed feature of length universal?

(3) Does the proposed new feature meet the naturalness condition by having a phonetic correlate?

(4) Which alternative best handles the facts of this particular language?

In general "economy" is a difficult factor to evaluate. No strict criteria have been set up, and "feature counting" is at best only a general guideline. Thus our discussion in this area will have to be highly subjective. The use of geminate clusters means the repetition of a matrix of identical features in adjoining segments; whereas with length as a feature lengthening rules produce no new segments and require only one additional feature in the matrix. Also the specification of environments (cf. rule 3) is made simpler with a feature of length. The use of geminate clusters might, however, be simplified by a redundancy rule applied after the phonological rules.[3] Such a redundancy rule would have the effect that an unmarked vowel following another vowel would receive the feature specifications of the first vowel in the cluster. The marked case would allow for diphthongs and for the relatively uncommon instances of two-vowel sequences which are neither diphthongs nor amenable to contraction rules.

A further complication results when a rule acts upon a geminate vowel (as in rule 3). In this case the rule would have to change specifications in two segments instead of in one. The following is rule (3) stated with a geminate vowel instead of a feature of length.

(4) $$\begin{bmatrix}+\text{voc}\\-\text{cons}\\-\text{high}\\-\text{low}\end{bmatrix}_1 \begin{bmatrix}+\text{voc}\\-\text{cons}\\-\text{high}\\-\text{low}\end{bmatrix}_2 \Longrightarrow [+\text{low}]_1 \; [+\text{low}]_2$$

This treatment appears to be intrinsically more complex than the first statement of rule (3).

It is difficult to determine the universality of any proposed new feature. All that can be said is that there are many languages that contain phonetically long vowels, and that there are some scholars who have used a feature of length in systematic descriptions. It is also possible that "long" vowels and "geminate" vowels are distinct entities. Not every "universal" feature is truly pertinent (i.e. non-redundant) to every language. This could well be true of a feature of length. It is possible that Greek could have geminate vowels and have no use for a feature of length (if such a feature does indeed exist) or vice versa. Thus the question is left to be decided within the sound system of Greek itself.

Phonetically Greek has long vowels. This was already established in ancient linguistic commentaries (e.g. the Alexandrians, etc.) and treatises on poetry. As such it would not likely violate the naturalness condition to propose a feature of length. On the other hand such a proposal is not made more <u>likely</u> by the naturalness condition but only more plausible. As Postal (1968:56n) puts it: (emphasis added)

> "Systematic phonemics...recognizes phonetic structure as providing a substantial, but <u>far from complete</u>, portion of the information relevant for the determination of the phonological structure..."

The first three criteria discussed above seemingly strongly favor the use of a feature of length. However, the fourth

criterion is by far the most important; it discourages the use of a feature of length and encourages the use of geminate vowels. So far, the problem of Greek tonal accent has not been touched on. Attic Greek had three tones--acute (high), grave (low), and circumflex (high-low glide). The high-low glide is a fusion of high and low tones on two successive morae. The most acceptable description within the generative framework as it now stands is to have two separate segments with a high tone on the first and a low tone on the second. This avoids the difficulties implicit in having a single segment marked [+long] and containing a fused tone.

There are no occurrences of a low-high glide in Greek. In places where one would expect to find a low-high glide there is always only a single high tone for the geminate vowels. The most plausible explanation for this is that a low-high sequence always changes to a high-high sequence--consequently fusing into a single high tone. Lieberman (1966) also substantiates this by pointing out that a low-high glide is much more highly marked in human language than a high-low glide.

This also solves several pressing problems in Greek tone placement. Circumflex accent (high-low glide) never occurs before the penultimate syllable, and when it occurs it is always on a long vowel. If it is true that all long vowels in Greek are described as geminates, then high-low glides can only occur in places where vowels containing high and low tone

have contracted. This is in fact the case (although some other factors are involved). All inflections in Greek which involve contraction with final stem vowels contain no more than two syllables. Thus the high-low glide is always limited to either the ultimate or penultimate syllable. High tone may occur on any of the last three syllables of a word, and only one syllable per word may have this high tone. It is assumed that all syllables that are not high tone or high-low glide are low tone. This is attested by the Alexandrian grammarians.

When an antepenult vowel with high tone becomes geminate because of the late compensatory lengthening rules, the result is a fused high-high accent and never a high-low glide. This is expected since there is no reason for the final segment in a geminate vowel to assimilate to all features of the initial segment and not assimilate to its tone as well. Thus where tone is concerned contracted vowels retain many of the properties of single segments. This is illustrated in the following examples.

nó-os → nôos 'mind'
mná-aa → mnâa 'mina'
} contraction with fused accent

timá-ns → timáas 'honor'
oikiá-ns → oikiáas 'house'
} compensatory lengthening with retention of acute accent

All of this discussion serves only to emphasized that in some ways long vowels must be regarded as dual segments with

identical feature specifications and in other instances long vowels function as single segments with some property vaguely defined as 'long'. In this paper the feature [long] will be used as a notational expedient. A 'plus' specification of this feature will be an abbreviation for a dual matrix which functions as a single segment. A full specification of a dual matrix will be used in rules where the generalization seems to require it.

2.1 Assimilation

Two of the most general rules of Attic Greek involve the assimilation of voice and aspiration of stops across morpheme boundaries. This is illustrated by the following examples of the application of rule (7)(given below):

UNDERLYING	SURFACE	
tetrib-tai	tetriptai	(rub) [4]
dedek^{h}-tai	dedektai	(take)
plek-t^{h} æ'nai	plek^{h}t^{h} æ'nai	(twist)
eleip-t^{h} æ'n	eleip^{h}t^{h} æ'n	(leave)
grap^{h}-d æ'n	grabd æ'n	(write)
dedek^{h}-mai	dedegmai	(take)
peplek-mai	peplegmai	(twist)
el æ'legk^{h}-mai	el æ'leggmai	(dishonor)
tetrib-t^{h}on	tetrip^{h}t^{h}on	(rub)

Initial examination of the data seems to point to the necessity of two rules for describing this phenomenon. Namely:

(5) $\begin{bmatrix} +\text{cons} \\ -\text{nas} \\ -\text{cont} \end{bmatrix} \longrightarrow [\alpha\text{voice}] \; / \; \_\_ \; [+\text{FB}] \begin{bmatrix} -\text{voc} \\ \alpha\text{voice} \end{bmatrix}$

(6) $\begin{bmatrix} +\text{cons} \\ -\text{nas} \\ -\text{cont} \\ -\text{voice} \end{bmatrix} \longrightarrow [\alpha\text{HSP}] \; / \; \_\_ \; [+\text{FB}] \begin{bmatrix} -\text{voc} \\ \alpha\text{HSP} \end{bmatrix}$

There is a minor problem in ordering these two rules. In either order they will produce intermediate forms that are voiced aspirated stops. There are at least two ways of avoiding this. The first is to assume a marking convention which will automatically specify any aspirated stops as [-voice] . However, a similar convention is then needed to specify that any voiced stop will be specified as [-HSP] . This solution may involve valid assumptions, but it is somewhat unwieldy, and simpler solutions present themselves.

These two rules are strikingly similar to each other. Such similarity would indicate the possibility of combining them into a single schema, but existing notational conventions do not permit this. The following angle-bracket convention will be used:[5]

(7) $\begin{bmatrix} +\text{cons} \\ -\text{nas} \\ -\text{cont} \end{bmatrix} \longrightarrow \begin{bmatrix} \langle\alpha\text{voice}\rangle_1 \\ \langle\beta\text{HSP}\rangle_2 \end{bmatrix} \; / \; \_\_ \; [+\text{FB}] \; \begin{bmatrix} -\text{voc} \\ \langle\alpha\text{voice}\rangle_1 \\ \langle\beta\text{HSP}\rangle_2 \end{bmatrix}$

This rule states that stem final stops are simultaneously assimilated to both voicing and aspiration of an inflection-initial consonant. This simultaneity eliminates the need for ordering and for the marking conventions mentioned above.

2.2 Spirantization

The output of the above rules is modified by a spirantization rule.

$$(8)\quad [-\text{cont}] \longrightarrow [+\text{cont}] \;/\; \begin{bmatrix} \_\_\_\_ \\ +\text{cor} \\ -\text{nas} \end{bmatrix} [+\text{FB}] \begin{bmatrix} +\text{cor} \\ -\text{nas} \\ -\text{cont} \end{bmatrix}$$

Simply stated, the first segment in a cluster of alveolar stops will become /s/ as in the following examples:

underlying form	rule (7) applied	rule (8) applied
pepeit^{h}-tai	pepeit-tai	pepeistai (persuade)
epeit^{h}-t^{h}æ'n	------	epeist^{h}æ'n (persuade)
æ'd-tai	æ't-tai	æ'stai (eat)
k^{h}ariet-teros	------	k^{h}ariesteros (graceful)
oid-t^{h}a	eit^{h}-t^{h}a	oist^{h}a (know)

This rule never produces <u>zeta</u>. Whatever the true specification of <u>zeta</u> is, it is almost surely voiced as well as continuant (or perhaps affricated). Thus one might expect that /t/ followed by /d/ should become /z/. Unfortunately I have found no examples of the above sequence and there are no examples of <u>zeta</u> ever participating in a consonant cluster (ancient

sources indicate that zeta was a consonant cluster in a way similar to ksi or psi). Zeta definitely does not function as a simple voiced counterpart of /s/.

2.3 Stop Cluster Simplification

The only clusters of stops allowed in Greek are those composed of homorganic stops and those in which the second segment is coronal. This is a very important aspect of Greek phonology, but it is almost vacuous when applied to changes of consonants at morpheme boundaries. There are no inflexions in Greek which begin with labial stops and only one inflection which begins with a velar stop. This single representative is the ending /-ka/ used in the aorist of several Greek verbs. The stop clusters are simplified as in the following examples:

underlying form	assimilation rule (7)	loss rule (9)	
pepeit^{h}-ka	pepeit-ka	pepeika	(persuade)
kekomid-ka	kekomit-ka	kekomika	(supply)

It is possible to write a very general phonological rule which would reflect the morpheme structure rule that simplifies consonant clusters. Such a phonological rule describes not only the two examples above but also all possible combinations of consonants across morpheme boundaries. This rule is vacuous over almost the entire range of its application because of the fortuitous lack of inflections beginning with labial stops (as

well as voiced or appirated velar stops).

(9) $\begin{bmatrix}+\text{cons}\\-\text{cont}\\+\text{cor}\end{bmatrix} \longrightarrow \emptyset \;/\; \underline{\quad} \begin{bmatrix}+\text{cons}\\-\text{cor}\end{bmatrix}$

2.4 Rules Affecting Nasals

There is one general rules which was recognized by ancient authorities and is now a showpiece in school grammars of Greek, i.e. a gamma (otherwise representing /g/) represents an /ŋ/ before another velar. This is the orthographic way of representing the assimilation of a nasal to the position of a following stop. This assimilation occurs both formative-internally and across formative boundaries. The lexical representation is simply [+nasal] with a general redundancy rule providing the features of an alveolar nasal. Phonological rule (10) then applies.[6]

(10) $[+\text{nas}] \longrightarrow \begin{bmatrix}\alpha\,\text{cor}\\ \beta\,\text{ant}\end{bmatrix} \;/\; \underline{\quad} \begin{bmatrix}\alpha\,\text{cor}\\ \beta\,\text{ant}\\ -\text{cont}\end{bmatrix}$

/ŋ/ is not a systematic phoneme and is produced only by this rule.

Any labial consonant becomes a nasal when it prededes /m/.

(11) $[-\text{nas}] \longrightarrow [+\text{nas}] \;/\; \begin{bmatrix}\underline{\quad}\\-\text{cor}\\+\text{ant}\end{bmatrix} \begin{bmatrix}-\text{cor}\\+\text{ant}\\+\text{nas}\end{bmatrix}$

The following examples illustrate rule (11). Notice that the aspiration and voicing assimilation rules are applicable first.

underlying form	rule (7)	rule (11)	
errip^{h}-met^{h}a	errib-met^{h}a	errimmet^{h}a	(throw)
leleip-mai	leleib-mai	leleimmai	(leave)
tetrib-mai	-----	tetrimmai	(rub)
gegrap^{h}-mai	gegrab-mai	gegrammai	(write)

Three-consonant sequences also result from rules (7) and (11):

kekamp-mai	kekamb-mai	kekammmai	(bend)
pepemp-mai	pepemb-mai	pepemmmai	(send)
el æ'lenk^{h}-mai	elæ'leng-mai	-----	(dishonor)

When sequences of nasals such as /mmm/ would thus be produced one is dropped by the following rule:

(12) $[-\text{cor}][-\text{cor}][+\text{FB}]\begin{bmatrix}-\text{cor}\\+\text{ant}\\+\text{nas}\end{bmatrix}$

1 2 3 4 $\Longrightarrow$ ø 2 3 4

It should be noted that this rule also applies to sequences such as /ngm/ (thus producing /gm/ which may be generated by earlier rules. Rules (10) and (12) are unordered with respect to one another. Sequences such as /ngm/ would be changed to /ŋgm/ by rule (10) and than simplified to /gm/ by rule (12). The reverse order achieves the same result, and there is no other data which would dictate a specific order. For the sake of simplicity, rule (10) will be ordered after rule (12)

so that it (i.e. rule (10)) will need to be applied fewer times. Thus the ordering in such a case is dictated not by constraint but by the generative process itself. It would seem reasonable that one should consider a simplicity metric not only within individual rules and schema but also within the application of entire rule systems. The optimal grammar would contain not only the simplest and fewest rules but also the smallest number of rule applications.[7]

2.5 Vowel Clusters

As was stated in the introduction, vowels provide the greatest problems in Greek phonology, both because of orthography and because they seem to participate more often in exceptional situations. This latter phenomenon is most evident in such items as proper names where often the oblique forms behave in a seemingly capricious and non-general way.

2.6 Alpha-shift

One of the best known features of Attic phonology is the shift of the sound represented by long alpha to the sound represented by eta. This was almost certainly the shift of a long unrounded low back vowel /a'/ to its front counterpart /æ'/. Short vowels did not participate in the change. Furthermore there are some exceptions to this change in Attic although the shift was complete in Ionic and non-existent in the other major dialects.

The exceptions to the alpha-shift rule in Attic are very regular. The shift simply did not take place after the sounds represented by epsilon, iota, and rho. These three sounds probably formed a natural class with the following specifications:

$$\begin{bmatrix} +\text{voc} \\ -\text{back} \\ -\text{low} \\ -\text{lateral} \end{bmatrix}$$

The fact that the shift did not affect short vowels is quite important in rule ordering due to the fact that Greek contains both shortening and lengthening rules. A good example of this is the plural of the first declension feminine nouns. The stem final vowel in the first declension is /a'/. Under normal conditions it would be expected to follow the alpha-shift rule, but the plural forms contain unshifted short /a/ as in the following examples.

	underlying form	surface form
nom. plur.	timaa-i	tima-i (honor)
	politaa-i	polita-i (citizen)
	kritaa-i	krita-i (judge)
	mnaa-i	mna-i (mina)
	sukaa-i	suka-i (fig tree)

Parallel cases also occur in certain contract verb forms. Inspection of the data shows that these short forms occur before inflections beginning with /i/. Thus there is a

shortening rule which must precede the alpha-shift.

$$(13)\quad [+\text{long}] \longrightarrow [-\text{long}] \;/\; \begin{bmatrix} \underline{\quad} \\ +\text{voc} \\ -\text{cons} \\ +\text{low} \\ +\text{back} \end{bmatrix} [+\text{FB}] \begin{bmatrix} +\text{voc} \\ -\text{cons} \\ +\text{high} \\ -\text{back} \end{bmatrix}$$

The feature [long] here (and hereafter) is used as an abbreviatory device to indicate a dual segment with common feature specifications.

The alpha-shift itself must be stated with two rules.

$$(14)\quad [+\text{back}] \longrightarrow [-\text{rule 15}] \;/\; \begin{bmatrix} +\text{voc} \\ -\text{back} \\ -\text{low} \\ -\text{lat} \end{bmatrix} \begin{bmatrix} \underline{\quad} \\ +\text{voc} \\ -\text{cons} \\ +\text{low} \\ +\text{long} \end{bmatrix}$$

$$(15)\quad [+\text{back}] \longrightarrow [-\text{back}] \;/\; \begin{bmatrix} \underline{\quad} \\ +\text{voc} \\ -\text{cons} \\ +\text{low} \\ +\text{long} \end{bmatrix}$$

These two rules account for the following derivations:

tima' → tim æ' (honor)

polita's → polit æ's (citizen)

krita's → krit æ's (judge)

stratiɔ'ta's → stratiɔ't æ's (general)

poi æ'ta's → poi æ't æ's (poet)

The following illustrate rule(14):

k^h ɔra' → unchanged (land)

oikia' → unchanged (house)

tamia's → unchanged (steward)

Exception rules are discussed twice in The Sound Pattern of English, and are met with little favor in either instance. However, no viable alternative was offered, and there likewise seems to be no alternative to the above rule.

2.7 Simplification of Sibilant Clusters

All coronal consonants are dropped before /s/. When the dropped segment is a nasal the preceding contiguous vowel is lengthened. This problem is best handled by two rules, due to the fact that sequences such as /nts/ occur in which both coronals must be dropped and the vowel must be lengthened. Both rules are justified independently elsewhere in the phonology.

(16) $$\begin{bmatrix} +seg \\ +cons \\ +cor \\ -nas \\ -cont \end{bmatrix} \quad [+strid]$$

$$1 \qquad 2 \quad \Longrightarrow \quad \emptyset \quad 2$$

as in:

k^hariet-si → k^hariesi (graceful)

elpid-s → elpis (hope)

k^harit-s → k^haris (grace)

ornit^h-s → ornis (bird)

(17) $\begin{bmatrix}+\text{voc}\\-\text{cons}\end{bmatrix}\begin{bmatrix}+\text{cor}\\+\text{nas}\end{bmatrix}\ [+\text{strid}]$

$1 \qquad 2 \qquad 3 \Longrightarrow 1\ 1\ 3$

as in:

melan-s → melaas (black)

en-s → ees (one)

luo-nsi → luoosi (loose)

luon-sa → luoosa (loose)

The following examples illustrate the combined effect of the two rules:

underlying form	rule (16)	rule (17)
pant-si	pan-si	paasi (all)
gigant-s	gigan-s	gigaas (giant)
deeknunt-s	deeknun-s	deeknuus (show)
leont-si	leon-si	leoosi (lion)

Obviously the ordering is crucial.

It should be noted that the lengthening in rule (17)must be ordered later than the lowering of lengthened mid vowels. The long mid vowels that result from sibilant cluster simplification are represented orthographically by the spurious diphthongs rather than by eta and omega. This also reflects the historical ordering of the two processes.

The nasal deletion and lengthening rule must be ordered after the alpha-shift rules. There are no examples of /æ'/

being produced from an /a'/ that is the product of nasal deletion. The following is an example of this in the accusative plural of first declension feminine nouns:

tima-ans "honor"
tima-aas (nasal deletion and compensatory lengthening)
timaas (vowel contraction and boundary deletion)

2.8 Constraints on Cluster Length

The above example illustrates the fact that no syllable peaks in Greek can be composed of more than two vowel segments. The two-segment peaks are always composed of a long vowel or a diphthong with a short initial vowel. Long diphthongs (i.e. diphthongs with long first elements) are found in very early Greek but were lost before the Attic period. This reduction always involved either the shortening of the first element of the loss of the second element. This does not rule out the possibility of longer vowel sequences (e.g. tamiaas "steward") but only restricts the length of syllable peaks. For instance /tamiaas/ is a three-syllable word, otherwise it could not have three vowel segments in succession. Nor can this be accounted for by a universal constraint. Many languages have three or more degrees of phonetic length produced by various processes of contraction and consonant deletion.

Such constraints are difficult to describe within a generative framework because it lacks an adequate theory of syllabicity. Thus any rule that would restrict the length of vowel sequences produced by lengthening or contraction

might also truncate sequences which involve more than one syllable. Even if an accurate output could be produced by elaborately analyzing and specifying sequences involved in contractions as opposed to sequences across syllables, it would still basically be a problem of boundaries rather than of segments. The former approach would be observationally adequate but not descriptively adequate.

2.9 Vowel Contractions

The following chart gives the feature specifications for Greek vowels at the vowel contraction stage in the generative process:[8]

	i	e	æ'	a	u	o	ɔ'
high	+	-	-	-	+	-	-
low	-	-	+	+	-	-	+
round	-	-	-	-	+	+	+
back	-	-	-	+	+	+	+
long	-	-	+	-	-	-	+

Under normal conditions stem final vowels contract with the initial vowels of inflectional endings. Thus:

o + a = ɔ'
æ' + a = æ'
æ' + e = æ'
e + ɔ' = ɔ'
e + æ' = æ'
o + æ' = ɔ'
æ' + ɔ' = ɔ'

a + o = ɔ'
a + ɔ' = ɔ'
o + e = o'
e + o = o'
a + e = a'
a + æ' = a'
e + a = æ'

æ' + o = ɔ'
o + ɔ' = ɔ'
ɔ' + e = ɔ'
ɔ' + a = ɔ'
ɔ' + o = ɔ'

Given the above data, four conclusions may by drawn:

(1) Only non-high vowels are contracted.

e.g. gera-i — gerai (gift)

eu — eu (well)

hæ'rɔ'-i — hæ'rɔ'i (hero)

(2) The contraction is always long in quantity.

(3) There are dominant features in the contracting process i.e. certain features which if present will also be present in the contraction.

a. if either contract vowel is [+round] the contraction will be [+round].

b. if either contract vowel is [+low] the contraction will be [+low].

(4) If neither of the contract vowels is [+round] the specification of [back] for the contraction will be the same as that of the first contract vowel.

Proposition (3) requires two mirror image rules. Although this kind of rule has been discussed to some extent in recent literature (Langacker 1969) there is as yet no generally accepted formulation for them. A mirror-image rule has the effect that a particular change comes about when a particular environment either follows or precedes the changed element. In vowel contractions this is even more complicated because there are two segments which become one segment. This contraction process will be handled as a single final rule.

Propositions (3) and (4) describe assimilation. Lack of a (____) in the second environment of the following rules indicates that the changed element may occur either before or after that environment.

(18) $[\pm\text{round}] \longrightarrow [+\text{round}] \;/\; \left[\begin{matrix}\underline{\quad\quad}\\ +\text{voc}\\ -\text{cons}\\ -\text{high}\end{matrix}\right] \;/\; \left[\begin{matrix}+\text{voc}\\ -\text{cons}\\ -\text{high}\\ +\text{round}\end{matrix}\right]$

(19) $[-\text{low}] \longrightarrow [+\text{low}] \;/\; \left[\begin{matrix}\underline{\quad\quad}\\ +\text{voc}\\ -\text{cons}\\ -\text{high}\end{matrix}\right] \;/\; \left[\begin{matrix}+\text{voc}\\ -\text{cons}\\ -\text{high}\\ +\text{low}\end{matrix}\right]$

These two rules may be combined using the angle-bracket notation used above. Thus:

(20) $\left[\begin{matrix}\langle -\text{round}\rangle_1\\ \langle -\text{low}\rangle_2\\ +\text{voc}\\ -\text{cons}\\ -\text{high}\end{matrix}\right] \longrightarrow \left[\begin{matrix}\langle +\text{round}\rangle_1\\ \langle +\text{low}\rangle_2\end{matrix}\right] \;/\!/\; \left[\begin{matrix}+\text{voc}\\ -\text{cons}\\ -\text{high}\\ \langle +\text{round}\rangle_1\\ \langle +\text{low}\rangle_2\end{matrix}\right]$

The back assimilation rule (proposition 4) is stated thus:

(21) $\left[\begin{matrix}+\text{voc}\\ -\text{cons}\\ -\text{high}\\ -\text{round}\end{matrix}\right] \longrightarrow [\alpha\text{back}] \;/\; \left[\begin{matrix}+\text{voc}\\ -\text{cons}\\ -\text{high}\\ \alpha\text{back}\\ -\text{round}\end{matrix}\right] \;\underline{\quad\quad}$

After all features in the contract segments have been assimilated by the three preceding rules, it then becomes possible to apply a contraction convention. It will be assumed that these assimilations occur before the contraction, when in reality they should be considered simultaneous with the contraction.

The contraction convention is devised to handle the problem of length. [long] is included in both matrices (even though they both can be plus or minus) in order to show that any contraction of two, three, or four segments will always result in only two segments; and to account for the fact that [long] is really not a feature which can be specified (at least in this treatment) by redundancy or morpheme structure rules.

(22)
$$\begin{bmatrix} +\text{voc} \\ -\text{cons} \\ -\text{high} \\ \alpha\text{long} \end{bmatrix}_1 \begin{bmatrix} +\text{voc} \\ -\text{cons} \\ -\text{high} \\ \beta\text{long} \end{bmatrix}_2 \Rightarrow [+\text{long}]_1$$

2.10 List of Rules

Numbers in parentheses to the right of each rule are the numbers found in the text.

(1) $\begin{bmatrix}+\text{voc}\\-\text{cons}\\-\text{high}\\-\text{low}\end{bmatrix}\begin{bmatrix}+\text{son}\\+\text{cons}\end{bmatrix}[+\text{FB}]\,[+\text{strid}]\,[+\text{WB}]$ (2)

$1 \quad 2 \quad 3 \quad 4 \quad 5 \Longrightarrow 1\ 1\ 2\ 3\ \emptyset\ 5$

(2) $[-\text{low}] \longrightarrow [+\text{low}] \;/\; \begin{bmatrix}\underline{\quad}\\+\text{voc}\\-\text{cons}\\-\text{high}\\+\text{long}\end{bmatrix}$ (3)

(3) $\begin{bmatrix}+\text{cons}\\-\text{nas}\\-\text{cont}\end{bmatrix} \longrightarrow \begin{bmatrix}\langle\alpha\,\text{voice}\rangle_1\\\langle\beta\,\text{HSP}\rangle_2\end{bmatrix} \;/\; \underline{\quad}\,[+\text{FB}]\begin{bmatrix}-\text{voc}\\\langle\alpha\,\text{voice}\rangle_1\\\langle\beta\,\text{HSP}\rangle_2\end{bmatrix}$ (7)

(4) $[-\text{cont}] \longrightarrow [+\text{cont}] \;/\; \begin{bmatrix}\underline{\quad}\\+\text{cor}\\-\text{nas}\end{bmatrix}[+\text{FB}]\begin{bmatrix}+\text{cor}\\-\text{nas}\\-\text{cont}\end{bmatrix}$ (8)

(5) $\begin{bmatrix}+\text{cons}\\-\text{cont}\\+\text{cor}\end{bmatrix} \longrightarrow \emptyset \;/\; \underline{\quad}\;\begin{bmatrix}+\text{cons}\\-\text{cor}\end{bmatrix}$ (9)

(6) $[-\text{nas}] \longrightarrow [+\text{nas}] \;/\; \begin{bmatrix}\underline{\quad}\\-\text{cor}\\+\text{ant}\end{bmatrix}\begin{bmatrix}-\text{cor}\\+\text{ant}\\+\text{nas}\end{bmatrix}$ (11)

(7) $[-\text{cor}]\,[-\text{cor}]\,[+\text{FB}]\begin{bmatrix}-\text{cor}\\+\text{ant}\\+\text{nas}\end{bmatrix}$ (12)

$1 \quad 2 \quad 3 \quad 4 \Longrightarrow \emptyset\ 2\ 3\ 4$

(8) $\left[+nas\right] \longrightarrow \begin{bmatrix} \alpha cor \\ \beta ant \end{bmatrix} / \_\_\_ \begin{bmatrix} \alpha cor \\ \beta ant \\ -cont \end{bmatrix}$ (10)

(9) $\left[+long\right] \longrightarrow \left[-long\right] / \begin{bmatrix} \_\_\_\_ \\ +voc \\ -cons \\ +low \\ +back \end{bmatrix} \left[+FB\right] \begin{bmatrix} +voc \\ -cons \\ +high \\ -back \end{bmatrix}$ (13)

(10) $\left[+back\right] \longrightarrow \left[-rule\ 11\right] / \begin{bmatrix} +voc \\ -back \\ -low \\ -lab \end{bmatrix} \begin{bmatrix} \_\_\_\_ \\ +voc \\ -cons \\ +low \\ +long \end{bmatrix}$ (14)

(11) $\left[+back\right] \longrightarrow \left[-back\right] / \begin{bmatrix} \_\_\_\_ \\ +voc \\ -cons \\ +low \\ +long \end{bmatrix}$ (15)

(12) $\begin{bmatrix} +seg \\ +cons \\ +cor \\ -nas \\ -cont \end{bmatrix} \left[+strid\right]$ (16)

1 2 $\Longrightarrow$ $\emptyset$ 2

(13) $\begin{bmatrix} +voc \\ -cons \end{bmatrix} \begin{bmatrix} +cor \\ +nas \end{bmatrix} \left[+strid\right]$ (17)

1 2 3 $\Longrightarrow$ 1 1 3

(14) $\begin{bmatrix} \langle \text{-round} \rangle_1 \\ \langle \text{-low} \rangle_2 \\ \text{+voc} \\ \text{-cons} \\ \text{-high} \end{bmatrix} \longrightarrow \begin{bmatrix} \langle \text{+round} \rangle_1 \\ \langle \text{+low} \rangle_2 \end{bmatrix} \Big/ \begin{bmatrix} \text{+voc} \\ \text{-cons} \\ \text{-high} \\ \langle \text{+round} \rangle_1 \\ \langle \text{+low} \rangle_2 \end{bmatrix}$ (20)

(15) $\begin{bmatrix} \text{+voc} \\ \text{-cons} \\ \text{-high} \\ \text{-round} \end{bmatrix} \longrightarrow [\alpha\text{back}] \Big/ \begin{bmatrix} \text{+voc} \\ \text{-cons} \\ \text{-high} \\ \alpha\text{back} \\ \text{-round} \end{bmatrix} \text{——}$ (21)

(16) $\begin{bmatrix} \text{+voc} \\ \text{-cons} \\ \text{-high} \\ \alpha\text{long} \end{bmatrix}_1 \begin{bmatrix} \text{+voc} \\ \text{-cons} \\ \text{-high} \\ \beta\text{long} \end{bmatrix}_2 \Longrightarrow [\text{+long}]_1$

CONCLUSION

The foregoing rules provide a partial statement of the morphophonemics of Attic Greek. It was shown that among consonants the systematic phonemes lie rather near the surface (i.e. they undergo subjectively less radical changes), but that the underlying vowel system tends to be much more abstract. Five systematic vowel phonemes have twelve manifestations on the systematic phonetic level. Most of the changes involve some sort of boundary phenomena which can be explained in traditional terms (assimilation, contraction etc.). However, no traditional treatment of Greek phonology has been so precise or so formal; nor has any traditional treatment been based on an investigation of the actual sounds of Attic rather than simply on the orthography. Traditional descriptions were motivated by the fact that Attic Greek has become only a literary language and that phonetic investigations beyond the orthography have been difficult.

Certain portions of the phonology have been selectively omitted from this treatment. Word boundary changes fall into this category. Elision, hiatus, and crasis are manifested primarily in poetry and similarly artificial situations. It is likely that these reflected real speech in many ways,

but their interest to the linguist is somewhat marginal.

One non-marginal topic omitted here is that of tonal accent. Many problems remain in this area and in many ways they seem to be the most interesting problems. Previous work has been from a diachronic Indo-European point of view. It is hoped that future linguists will take a more active interest in the synchronic aspects of Greek tone. It would seem that such an interest awaits a more precise formulation of "syllable" and "mora" withingthe generative framework.

SAMPLE DERIVATIONS

SAMPLE DERIVATIONS

(1) tim a' - i (tima'-i)

	+voc	+voc
	-cons	-cons
	+low	+high
	+back	-back
	+long	

-long rule 9

tim a - i (tima-i)

(2) polit a' - s (polita'-s)

	+voc
	-cons
	+low
	+back
	+long

-back rule 11

pplit æ' - s (politæ'-s)

(3) ger a - a (gera-a)

	+voc	+voc
	-cons	-cons
	-high	-high
	-long	-long

+long rule 16

ger a' (gera')

(4) tim a - o men (tima-omen)
+voc +voc
-cons -cons
-high -high
+low +round
-long -long

+round +low rule 14

+long rule 16

tim ɔ' men (timɔ'men)

(5) gen e - a (gene-a)
+voc +voc
-cons -cons
-high -high
-round +low
-back -round
-low +back
-long -long

+low rule 14

-back rule 15

+long rule 16

gen æ' (gen æ')

(6) p a n t - s i (pant-si)
+voc +cor +cons +strid
-cons +nas +cor
-nas
-cont

Ø rule 12

a a Ø rule 13

p a a - s i (paa-si)

(7) le o n - s (leon-s)
+voc +son +strid
-cons +cons
-high
-low

o o ø rule 1

+low +low rule 2

le ɔ' n (leɔ'n)

(8) gra p^h - m ai ($grap^h$-mai)
+cons -voc
-nas +voice
-cont -HSP
-cor -cor
+ant +ant
+nas

-HSP
+voice rule 3

+nas rule 6

gra m - m ai (gram-mai)

(9) pepei t^h - t ai ($pepeit^h$-tai)
+cons -voc
-nas -HSP
-cont +cor
+cor -nas
-cont

-HSP rule 3

+cont rule 4

pepei s - t ai (pepeis-tai)

(10) pepei t^h - k a (pepeit^h-ka)

+cons -voc
-nas +cons
-cont -HSP
+cor -cor
-ant

-HSP rule 3

∅ rule 5

pepei - k a (pepei-ka)

(11) erri p^h - m et^ha (errip^h-met^{h}a)

+cons -voc
-nas +voice
-cont -HSP
-cor -cor
+ant +ant
+nas

+voice rule 3
-HSP

+nas rule 6

erri m - m et^ha (errim-met^{h}a)

FOOTNOTES

FOOTNOTES

1 Redundancy rules have not been treated in this thesis. Thus the judgement that consonants present fewer problems than vowels is based entirely on the phonological rules presented here.

2 Jakobson considers quantity to be determined by the underlying feature "tense."

> "The three types of prosodic features which, following Sweet, we have termed tone, force, and quantity...find a close analogue in the three types of inherent features... The tense/lax opposition should, however, be detached from the sonority features and viewed as a separate "protensity" feature, which among the inherent features corresponds to the quantity features in the prosodic field." (Jakobson 1962)

3 It should be noted that such a redundancy rule is not possible within the current formalism of the generative framework. Thus some modification would be required which would permit language-specific redundancy rules that applied only after the phonological rules.

4 All glosses are in relation to the stem only. The suffixes are unrelated and untranslated.

5 The angle-bracket convention used here differs from that of Chomsky, Halle (1967 p.77) in that the convention used here does not invoove disjunctive ordering. Both rules in the schema (7) may be applied simultaneously if necessary.

6 This is the same assimilation rule found in many languages (including English).

7 Kiparsky (Bach & Harms 1968) presents evidence contrary to this conclusion. He states that feeding order is to be preferred over bleeding order rather than vice versa.

8 The long-vowel equivalents of the short vowels in this chart have been left out because they are considered to function as geminates. Their feature specifications are identical to their counterparts in the chart.

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