D. FORMAL JUSTIFICATION OF VARIABLES IN PHONEMIC CROSS-CLASSIFYING SYSTEMS

Variables in phonemic rules have proved extremely useful.[1-3] There is also a clear formal necessity that variables be included in any system with cross-classificatory features (whether or not the features are binary). If variables were not cost-free with respect to a simplicity criterion, the segments [+compact], [+grave] would appear to be related to each other in a more fundamental sense than the segments [-compact], [+grave]. But it is only an arbitrary decision to measure frontness in terms of gravity. '+grave' is exactly equivalent to '-acute': the value of the polarity of a given feature quality is not a substantive part of the theory. Therefore the metatheory requires that the features in a cross-classifying system are all marked:

$$[O \alpha F]$$

$$F \rightarrow \begin{matrix} \text{grave} \\ \text{compact} \\ \vdots \end{matrix}$$

$$\alpha \rightarrow \left\{ \begin{matrix} + \\ - \end{matrix} \right.$$

$$O \rightarrow \left\{ \begin{matrix} e \\ \sim \end{matrix} \right. \qquad \text{(by convention, the identity operation e is left blank)}$$

with the operations

$$\sim + = - \qquad e+ = +$$
$$\sim - = + \qquad e- = -$$

In phonemic matrices and nonvariable rules the value of O is usually affirmative, and a is specified with '+' or '-', but this is purely a convention; it would be exactly equivalent to maintain generally the value of $a = +$ and specify the phonemic matrices by the symbols '$\sim$' or 'e'.

The availability of different operators clearly shows that the segments [+compact], [-grave] are in as close a relation as [+compact], [+grave]. For instance, the assimilation rules

$$[\quad] \rightarrow [+\text{comp}] \text{ in the env} \underline{\quad\quad} [+\text{grave}]$$
$$\rightarrow [-\text{comp}] \text{ in the env} \underline{\quad\quad} [-\text{grave}]$$

are more simply combined

A) $[\quad] \rightarrow [a\text{comp}] \text{ in the env} \underline{\quad\quad} [a\text{grave}]$

and the assimilation rules

$$[\quad] \rightarrow [-\text{comp}] \text{ in the env} \underline{\quad\quad} [+\text{grave}]$$
$$\rightarrow [+\text{comp}] \text{ in the env} \underline{\quad\quad} [-\text{grave}]$$

are combined

B) $[\quad] \rightarrow [\sim a\text{comp}] \text{ in the env} \underline{\quad\quad} [a\text{grave}].$

If the front quality of segments were marked with acuteness instead of gravity, rules A) and B) would be equally simple: only the polarity is changed

A') $[\quad] \rightarrow [\sim a\text{comp}] \text{ in the env} \underline{\quad\quad} [a\text{acute}]$

B') $[\quad] \rightarrow [a\text{comp}] \text{ in the env} \underline{\quad\quad} [a\text{acute}].$

The arbitrariness of the polarity values is represented by the existence of cost-free variables that make $[+X] = [\sim -X']$ where X and X' are opposite extreme values along the same feature continuum (e.g. {acute, grave; abstract, concrete}).

In phonology the use of variables over + and - and operators covers various phenomena:

assimilation

$\qquad [\quad] \rightarrow [aX] \text{ in the env} \underline{\quad\quad} [aX]$

dissimilation

$\qquad [\quad] \rightarrow [\sim aX] \text{ in the env} \underline{\quad\quad} [aX]$

internal assimilation

$\qquad [aX] \rightarrow [aY]$

internal dissimilation

$\qquad [aX] \rightarrow [\sim aY]$

external environment specification

$$[\quad] \rightarrow [+X] / \underline{\qquad} [\alpha X] [\sim \alpha Y]$$

exchange (internal dissimilation)

$$[\alpha X] \rightarrow [\sim \alpha X]$$

If the exchange rule applies in a transformational cycle, the net effect is one of reciprocation with respect to the feature X. If the affected segment is contained within an odd number of constituents to which the exchange rule applies, the net effect is dissimilative; if it applies an even number of times, there is no net effect. (Sections XIV-E, XIV-F, and XIV-G present the use of such a rule in the Indo-European e/o ablaut.)

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E. THE RECIPROCATING CYCLE OF THE INDO-EUROPEAN E/O ABLAUT

The Indo-European (IE) e/o ablaut can be described by a reciprocating rule of the type discussed in Section XIV-D. The traditional presentation of the e/o ablaut is in terms of the cases, tenses or other derivations of the ablauting stems. An extremely telling observation is that words in compounds often have the opposite grade from the words alone.[1] This clearly indicates that the number of constituents in which the ablauting stem is contained is critical. In generative grammar, the combination of a morphophonemic cycle and an exchange rule is sensitive to the odd or even quality of the number of constituents. The IE rule is of the form

$$[\alpha grave] \rightarrow [\sim \alpha grave]$$

and it applies in a cycle. If the number of constituents containing the ablauting vowel is odd, the grade is changed; if it is even, the grade is unchanged. Sections XIV-F and XIV-G present the operation of this rule in Germanic and Greek. In the Germanic languages the scope of the ablaut is sharply restricted, but the similarity of the essential rule to that of Greek indicates that IE itself had a morphophonemic transformational

cycle that generated the e/o ablaut alternations.

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F. THE E/O ABLAUT IN OLD ENGLISH

The Germanic reflex of the Indo-European e/o ablaut appears in the nonreduplicating strong stems. The Germanic strong verbs, by Grimm's definition, show stem-vowel changes in derived forms. This analysis follows Keyser's suggestion that the historical distinction between the strong and weak stems is operative in Old English: strong stems are phonemically monosyllabic; weak stems, polysyllabic.[1]

The Germanic nonreduplicating verb ablaut occurs in 6 classes that are tradition-ally presented as 6 "ablaut series," each containing four forms. Since each of the classes is phonemically distinct, the entire set of series can be generated by 5 basic rules. Each rule is concerned with a single change in quality or quantity. This set occurs in a morphophonemic transformational cycle.

The traditionally presented "principal parts" of the old Germanic strong verb are: present infinitive, preterite singular, preterite plural, and past participle.

1. Past Participle

The strong verb past participle throughout old Germanic is generated by the rules

$$
\begin{bmatrix} +voc \\ -cons \end{bmatrix}
\begin{cases}
\rightarrow \emptyset \text{ in the env } \underline{\quad\quad} \begin{bmatrix} +voc \\ -cons \end{bmatrix} \\
\rightarrow [+grave] \text{ in the env } \underline{\quad\quad} [+sonorant]
\end{cases}
$$

Although these rules can be combined with the strong stem cycle, they will be omitted to simplify this presentation.

The relevant constituent structure is described by the rules

Verb → stem (+extension) — Mood

$$
\text{Mood} \rightarrow \text{PerNo} + \begin{cases} \text{indicative} \\ \text{subjunctive} \\ \text{infinitive} \\ \text{participle} \end{cases}
$$

$$
\text{PerNo} \rightarrow \begin{Bmatrix} 1 \\ 2 \\ 3 \end{Bmatrix} \begin{Bmatrix} \text{Sg} \\ \text{Pl} \end{Bmatrix}
$$

$$\text{Extension} \rightarrow \left\{ \begin{array}{l} + \text{ substantive} \\ + \text{ past} \end{array} \right\}$$

$$\left. \begin{array}{ll} \left\{ \begin{array}{c} 1 \\ 3 \end{array} \right\} & \text{sg} \rightarrow + \emptyset \\[2ex] \left\{ \begin{array}{c} 1 \\ 2 \\ 3 \end{array} \right\} & \text{pl} \rightarrow + \text{on} \end{array} \right\} \quad \text{in the env past } + \underline{\hspace{2cm}}$$

In Germanic, the ablauting of strong stems is restricted to the past tense or the derivation of nouns. This is represented by the optional stem extension: the cyclic rules will apply to an extended strong stem only. The actual morphophonemic value of the /+past/ stem extension is not critical, although it is probably $\emptyset$. This interpretation is not proposed as an ultimate solution: it merely represents the fact that the occurrence of the ablaut is limited in Germanic.

The form of the stems to which the stem cycle applies is

$$(((\# \text{ stem} + \text{Ext}) + \left\{ \begin{array}{c} \text{Sg} \\ \text{Pl} \end{array} \right\}) + \#)$$

and in the cases presented here

$$(((\# \text{ stem} + \text{Ext}) + \left\{ \begin{array}{c} \emptyset \\ \text{on} \end{array} \right\}) + \#),$$

where /+ext/ has the value /+past/. In OE the rule

C-1) $\quad [\alpha \text{grave}] \rightarrow [\sim \alpha \text{grave}]$ in the env $\boxed{\text{Long Syllable}}$

is a reciprocating rule of the type discussed in Section XIV-E. Among the Germanic languages this rule is restricted to OE because only in OE does the distinction between /æ/ and /a/ "re-emerge" from reconstructed Proto-Germanic.

The environment "Long Syllable" is the same as that formulated by Keyser for the weak verb cycle[1]:

$$[\text{+cons}] \ [\text{+voc}]_\alpha \ [\text{+son}]_\beta \ [\text{+cons}],$$

where $\alpha + \beta \geq 2$.

The cycle reflects the historical verb class derivation,[2,3] since it is fairly clearly divided into two sections: the first 3 rules apply critically to the first 3 classes and the final 2 rules apply critically to the last 3 classes. The fact that all the environments are included between $\# C_o^3 \underline{\hspace{1.5cm}} C$ blocks the application of rule C-1) to the vowel in /rid/ or /far/. It also blocks the application of rule C-4) to each vowel of /raad/ or the vowel of /band/ because rule C-4) is actually

$$[\text{+comp}]_1^1 \rightarrow [\text{+long}]_1^1 \text{ in the env } \# C_o^3 \underline{\hspace{1.5cm}} C + \text{ext} \left\{ \begin{array}{l} \emptyset \\ \text{+on} \end{array} \right.$$

The effect of the environment /+ext $\emptyset$/ is to limit the application of rules C-4-b) and C-5) to the first cycle, when nothing follows the /+ext/.

One incorrect form is generated by these rules — the preterite singular of /beeodon/.

It comes out /baaæd/ instead of the correct form /bæææad/, but the diphthong structure rules will correct this. In order not to violate the distinctness convention the diphthong structure rules need to be included at the beginning of the cycle.

The Old English <mark>strong</mark> Verb Cycle

	Pre-final restriction	Final restriction	
C-1) $[\alpha grave] \to [\sim\alpha grave]$ in the env	$\longleftrightarrow [+son] \longleftrightarrow$	no restriction	C-1
C-2) $[\quad] \to [+diff]$ in the env		$+\begin{bmatrix} +voc \\ -cons \end{bmatrix}$	C-2
C-3) $[\quad]_1^n \to \emptyset$ in the env	$\underline{\qquad} \begin{bmatrix} +voc \\ -cons \end{bmatrix}$	$+\begin{bmatrix} +voc \\ -cons \end{bmatrix}$	C-3
C-4) $[+comp]_1^1 \to [+long]_1^1$ a) in the env		$+\begin{bmatrix} +voc \\ -cons \end{bmatrix}$	C-4 a)
b) in the env		$\emptyset$	C-4 b)
C-5) $[\alpha comp] \to [\sim\alpha comp]$ in the env		$\emptyset$	C-5

All rules apply in the env $\begin{bmatrix} +voc \\ -cons \end{bmatrix}$, in extended strong stem only, i.e., the pre-final environment for rules C-1), C-2) is actually $\#C_0^3 \longleftrightarrow [+son]_1 \longleftrightarrow C_1$ +ext; for rule C-3): $\#C_0^3 [\underline{\qquad}]_1^n \begin{bmatrix} +voc \\ -cons \end{bmatrix} C_1$ +ext; and for rules C-4), C-5): $\#C_0^3 [\underline{\qquad}] C_1$ +ext.

Low-level rules

p) Past $\to \emptyset$

q) VV $\to \overline{V}$

r) Diphthong structure: $[+comp]_3 \to [-grave]_2 [+grave]$
(may be ordered before C-1)

Morphophonemically, long vowels are considered sequences of short vowels.

Class	Infinitive	Preterite Sg.	Preterite Pl.
1	rīdan	rād	ridon
2	bēodan	bǣad	budon
3	bindan	band	bundon
4	beran	bær	bǣron
5	metan	mæt	mǣton
6	faran	fōr	fōron

	−grave	+grave
+diffuse	i	u
{ −diffuse −compact }	e	o
+ compact	æ	a

OE Examples

(((# riid + ext) + ∅) + #)	Preterite Sg. — Class 1
(# ruud + ext)	C-1
(# raad + ext)	C-5
(# raad + ext + ∅)	New Cycle
(# rææd + ext + ∅ + #)	C-1
(# rææd + ext + ∅ + #)	New Cycle
(# raad + ext + ∅ + #)	C-1
# rād #	Low-Level Rules

(((# beeod + ext) + on) + #)	Preterite Pl. — Class 2
(# booed + ext)	C-1
(# baaæd + ext)	C-5
(# baaæd + ext + on)	New Cycle
(# bæææad + ext + on)	C-1
(# biiud + ext + on)	C-2
(# bud + ext + on + #)	New Cycle
# budon #	Low-Level Rules

(((# bind + ext) + on) + #)	Preterite Pl. — Class 3
(# bund + ext)	C-1
(# band + ext)	C-5
(+ band + ext + on)	New Cycle
(# bænd + ext + on)	C-1
(# bind + ext + on)	C-2
(# bind + ext + on + #)	New Cycle
(# bund + ext + on + #)	C-1
# bundon #	Low-Level Rules

(((# met + ext) + on) + #)	Preterite Pl. — Class 4
(# mæt + ext)	C-5
(# mæt + ext + on)	New Cycle
(# mē̄t + ext + on)	C-4
(# mǣt + ext + on + #)	New Cycle

OE Examples

$(((\text{\# met} + \text{ext}) + \text{on}) + \text{\#})$	Preterite Pl. — Class 4
$\text{\# mæton \#}$	Low-Level Rules
$(((\text{\# far} + \text{ext}) + \emptyset) + \text{\#})$	Preterite Sg. — Class 5
$(\text{\# fār} + \text{ext})$	C-4
$(\text{\# fōr} + \text{ext})$	C-5
$(\text{\# fōr} + \text{ext} + \emptyset)$	New Cycle
$(\text{\# fōr} + \text{ext} + \emptyset + \text{\#})$	New Cycle
$\text{\# fōr \#}$	Low-Level Rules

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G. THE E/O ABLAUT IN GREEK

The well-known alternations between the vowels _e_ and _o_ in verbal roots in Greek can be predicted from the constituent structure of the words in which these roots appear and a rule of the form

A. $[\alpha \text{grave}] \rightarrow [\sim \alpha \text{grave}]$ in env $\begin{bmatrix} -\text{diffuse} \\ -\text{compact} \\ -\text{cons} \end{bmatrix} X + Y \ (+\text{\#})$ where X, Y do not contain #

operating in a transformational cycle.

To show how this rule operates, we require a statement of the internal constituent structure of Greek verbs and of nominals derived from verbs. Despite all of the attention that linguists have paid to these forms in the past, no such formulation has ever been attempted for Greek. Consequently, the formulation that I present in this report below must be regarded as being highly provisional. To substantiate the claims that I make, or to refute them, we require a thorough statement of Greek syntax so that we can see how the rules embodying these claims fit into such a syntax.

1. Constituent Structure of the Verb

Ignoring for the moment the low-level selectional restrictions, the phrase structure of the Greek verb may be schematized by means of the following phrase structure rules:

P1.   V $\rightarrow$ (Augment) V_{base} Person Number (Voice)

P2. $V_{base} \rightarrow V_{stem}$ Theme (Mood)

P3. $V_{stem} \rightarrow V_{root}$ (Tense)

P4.   Voice $\rightarrow$ Middle

P5.   Mood $\rightarrow \begin{Bmatrix} \text{Imperative} \\ \text{Optative} \\ \text{Subjunctive} \end{Bmatrix}$

P6.   Tense $\rightarrow \begin{Bmatrix} \text{Present} \\ \text{Future} \\ \text{Aorist} \\ \text{Perfect} \\ \text{Passive (Future)} \\ \text{Aorist-Passive} \end{Bmatrix}$

When the voice constituent is missing, the verb is said to be in the active voice; without the mood constituent it is in the indicative mood, and without the tense constituent, it is in the second aorist tense and the augment constituent must be present. Only certain verbs can appear in the second aorist. In a complete Greek grammar, we shall probably want to introduce the constituents person, number, voice, and mood transformationally, but the statement given here is adequate for our purposes. We also ignore the problems of how to handle the "primary" and "secondary" person endings of the active voice, and the person endings in the perfect tenses.

The theme constituent is missing in certain tenses of certain verbs: for example, in the present tense of verbs whose present tense constituent is <u>nu</u>. This constituent is also missing in the perfect middle of all verbs; its absence here can be handled by the following deletion transformation:

T1.   Perfect   Theme   X   Middle
        1   2   3   4 $\rightarrow$ 1 0 3 4

The perfect constituent then permutes with the verbal root:

T2. V_{root} Perfect
      1   2 $\rightarrow$ 2 1

An additional constituent is then inserted after the root in the perfect active:

T3.   Perfect V_{root} Theme
      1   2   3 $\rightarrow$ 1 2+K 3

The constituents K and perfect are rewritten in the morphophonemics by the rules:

M1.   K $\rightarrow \begin{Bmatrix} \text{k in env } [\text{-cons}])_{V_{root}} + \rule{1cm}{0.4pt} \\ \phi \end{Bmatrix}$

$$M2. \quad \text{Perfect} \rightarrow \begin{cases} \text{a)} & e & \text{in env} \underline{\quad} + \begin{bmatrix} +\text{cons} \\ \alpha\text{vocalic} \end{bmatrix}_2 \\ \text{b)} & Ce & \text{in env} \underline{\quad} + C_1^1 \\ \text{c)} & VCV & \text{in env} \underline{\quad} + \begin{bmatrix} -\text{cons} \\ -\text{diffuse} \end{bmatrix} C_1^1 \\ \text{d)} & V & \text{in env} \underline{\quad} + V \end{cases}$$

Note that rule M2-c gives the "Attic reduplication."

Given this apparatus, we are able to predict the vocalism of verbal roots in e: we expect e-vocalism throughout the conjugation except in the perfect active tenses of verb roots that end in one or more consonants. Following the nomenclature of traditional Germanic grammars, we shall call such roots strong; roots that end in vowels, we shall call weak. Thus consider the conjugation of the verb from the strong verbal root streph, 'twist, turn': (we conjugate in the first person plural throughout)

1. Present active   (#(((+streph + $\emptyset$)+e)+men)+#):   stréphomen
2. Future active   (#(((+streph + s)+e)+men)+#):   strépsomen
3. Perfect active   (#(((+e+streph)+e)+a+men)+#):   estróphamen
4. Pluperfect active   (#(+e((+e+streph)+e)+e+men)+#):   ēstróphemen
5. Perfect middle   (#(+e+streph)+metha)+#):   estrámmetha

The a-vocalism in the perfect middle is a consequence of the zero-grade or vowel deletion rule, which I have not formulated here. Where we find full-grade in perfect middles of strong roots in e, we find the e-vocalism; thus for the root leip, 'leave', we have

6. Perfect middle   (#(+le+leip)+metha)+#):   leleímmetha

The conjugation of the weak verbal root kheu, 'pour' is exactly parallel to that of streph, except that in the perfect active tenses, the morpheme k given by rule M1 is present and the e-vocalism is maintained:

7. Perfect active   (#(((+khe+kheu+k)+e)+a+men)+#):   kekheúkamen.

Since the only form in which rule A applies an odd number of times to the vowel of the verbal root is in the perfect active tenses of strong verbs, only there do we find the o-vocalism in the root. In every other form it operates an even number of times; twice in the perfect middle and four times elsewhere.

2. Constituent Structure of Nominals Derived from Verbal Roots

It seems reasonable to suppose that the derivation of nominals from verbs in Greek is merely a special case of generalized transformations that embed into noun or adjective phrases deformations of full sentences in which the verb appears. The verbal root, together with a derivational affix, becomes the head noun or adjective in the phrase. The resulting noun must obtain a grammatical gender, and presumably it gets it from

derivational affix. I claim, for the moment without justification, that neuter and common gender affixes behave differently from affixes that are inherently feminine or masculine (by common gender affix, I mean an affix that is not inherently either masculine or feminine, but, depending on the derived word, it takes on one or another of these genders). The derived constituent structure of nouns having the first type of derivational affix is
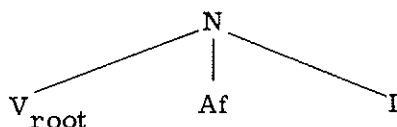
where I is the inflectional suffix, supplied transformationally, which marks the case and number of the noun. Nouns formed with the second kind of derivational affix have the structure
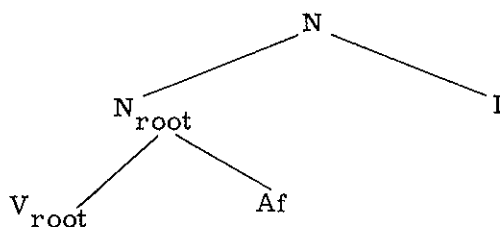
The neuter derivational affixes are es and mat: the common gender affixes are the agentive affixes tēr and tor; inherently feminine affixes are ā, id, and ad; inherently masculine affixes are o and eu. Given this derived structure, we are immediately able to account for the vocalism in derived nouns from verbal roots in e: derived neuter and agent nouns will have e-vocalism, whereas derived feminine and masculine nouns formed from the affixes just listed will have o-vocalism as illustrated by the following examples, in which we use the roots streph and blep, 'look':

8.	(#(+streph+mat+os)+#)	:	strémmatos, 'a twist'	Genitive singular
9.	(#(+blep+es+os)+#)	:	blépeos, 'a look'	
10.	(#(+streph+ter+os)+#)	:	streptêros, 'anything which turns'	
11.	(#((+streph+o)+s)+#)	:	stróphos, 'a band'	Nominative singular
12.	(#((+streph+eu)+s)+#)	:	stropheús, 'a vertebra'	
13.	(#((+streph+ā)+∅)+#)	:	strophá, 'a turning around'	
14.	(#((+streph+id)+s)+#)	:	strophís, 'a girdle'	
15.	(#((+streph+ad)+s)+#)	:	strophás, 'a circling'	

Weak verb roots that end in diffuse vowels also form derived nouns with the same ablaut relationship. For example, from the root kheu

16.	Genitive singular	(#(+kheu+mat+os)+#)	:	kheúmatos, 'a stream'
17.	Nominative singular	(#(+kheu+o)+s)+#)	:	khóos, 'a liquid measure'

18.   Nominative singular   (#(kheu+ā)+∅)+#)   :   khoā́, 'a libation'

and from the root dei, 'fear'

19.   Genitive singular   (#(+dei+es+os)+#)   :   déeos, 'fear'

3.   Extent of Ablaut in Greek

Verbal roots with fundamental vocalism o rather than e do not undergo ablaut. Thus,
although the verbal root kop 'strike' is strong, the vocalism of the perfect is not different
from that of the other tenses; the present active is kóptomen, and the perfect active is
kekóphamen.   Similarly, all nouns derived from this root have an o-vocalism: for
example, kómmatos, genitive singular, 'that which is struck'; kópos, nominative singu-
lar, 'a striking'; and kopís, nominative singular, 'a chopper'.   Furthermore, all pure
noun roots never exhibit ablaut.   Certain derivational and inflectional endings, however,
do show it, and in those cases in which it appears, it can be handled by rule A as before.
For example, the neuter affix es appears as os in the nominative and accusative sin-
gular.   But since there is a rule in Greek which deletes the nominative and accusative
singular marker in all neuter nominals not formed with the affix o, this alternation fol-
lows immediately from rule A.   Consider the nominative and accusative singular of
forms 9 and 19:

20.   (#(+blep+es)+#)   :   blépos

21.   (#(+dei+es)+#)   :   déos

The masculine affix o of examples 11 and 17 appears as e in the vocative singular
because the vocative singular marker has been deleted, so that rule A applies one less
time to it.   The affix eu, however, does not change in the vocative singular.

The theme of the verbal conjugation, which we have written e, also undergoes ablaut,
but rule A alone cannot give the correct results.   If, however, we suppose that there
is also a low-level phonetic rule in Greek,

$$e \rightarrow o \quad \text{in env} \underline{\quad} + [+\text{nasal}],$$

then the alternations of the theme vowel can be handled.

It is convenient, then, to set up a class of ablauting vowels in Greek: the e of verbal
roots, and the vowels of certain inflectional morphemes.   We are not forced, however,
to mark the distinction between ablauting and nonablauting vowels phonemically; we
require only a morphophonemic rule that will specially mark the ablauting vowels, and
an adjustment to rule A which will allow it to operate only on those vowels that are so
marked.

I am at present working on a system of rules which will account for the loss of vowels
in certain positions (the zero-grade phenomenon), vowel lengthening, and accent place-
ment.   This entire system is also, apparently, part of the transformational cycle in
Greek.

<div align="right">D. T. Langendoen</div>