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On stress and syllabification

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0. Introduction

Of all the diverse properties of segmental strings, syllable structure is the one that stress rules most often refer to. In fact, they refer to a quite specific aspect of syllable structure: syllable weight. Generally, it is this distinction between heavy and light syllables that affects the placement of stress. The richness of this problem is apparent from its ramifications. First, in many languages the notion ''heavy syllable'' invokes a disjunction of syllables containing a long vowel or diphthong and syllables with a short vowel but closed by a consonant. Second, though heavy syllables often attract the stress, they sometimes reject it or attract it subject to some limitations of, say, distance from a boundary. Third, the weight of some syllables may itself vary in a particular language, perhaps again under some boundary conditions. All of these issues are illustrated concretely in subsequent sections of this article.

   None of these observations is new, and previous work has not failed to attempt explanations of at least some of them. I know of four quite different approaches in the literature, discussed very briefly here.

0.1. Arrested Syllables

Allen (1973) offers an essentially physiological account based on Stetson's (1951) theory of syllables as chest-pulses. Allen holds that the oral arrest of closed (CVC) syllables is paralleled by thoracic arrest of long open (CVV) syllables. Another arrest, the arrest of ''stress pulses'', tends to be reinforced by these syllabic arrests, resulting in a general attraction of stress to CVC and CVV syllables.

   Although Allen's proposal has come under heavy criticism in some recent work (Hyman (1977a)), it nevertheless represents a unique attempt to explain why consonants and vowels form a natural class for stress rules solely in the postnuclear position of a syllable.

0.2. Stress and Duration

It is difficult to do justice here to Hyman's (1977a) analyses of a great variety of languages. In essence, his theoretical proposal is a functional one, depending crucially

on the observation that, all other things being equal, stressed syllables are longer than unstressed ones. Particular languages have perceptual or articulatory reasons for keeping some class of vowels short, so these vowels resist stressing, since it would inevitably cause them to lengthen. Probably the most common case of this is a language with phonemic vowel length. Since lengthening of short vowels under stress would tend to neutralize this length contrast, the speaker has a perceptual motivation to draw stress away from short vowels and maintain the phonemic contrast.

But Hyman also notes a problem for this theory. Many languages have rules of the sort "stress a heavy syllable, but if there isn't one, stress a light syllable", subject to the parameters "rightmost" and "leftmost". Therefore, he proposes a complementary tendency for heavy syllables to attract stress. It is the interplay of these two principles that yields the most common stress patterns.

One interesting result of Hyman's proposal will also come under discussion later. He recalls a universal principle attributed to Jakobson and Trubetzkoy that any language that contrasts syllable weight must also contain a vowel length contrast. According to his account, it is the perceptual motive of maintaining this vowel length contrast that induces the rejection of stress by short vowels in open syllables and the consequent stressing of heavy syllables.

0.3. Weak Clusters

Chomsky and Halle (1968) virtually propose two different theories of the role of syllable weight in phonological rules. The fundamental issue of this sort in English phonology is the behavior of so-called weak clusters, defined by Chomsky and Halle (1968, 83; slightly altered here):

$$
(1) \quad \text{Weak Cluster} \equiv \begin{bmatrix} +\text{syll} \\ -\text{tense} \end{bmatrix} C_0^1 \begin{bmatrix} -\text{syll} \\ +\text{son} \\ +\text{cont} \\ -\text{ant} \end{bmatrix}_0
$$

The two segments on the right select a single consonant or a cluster of a consonant plus a liquid or glide. So the segment on the left is a lax vowel in an open syllable. In view of Kahn's (1976) extension of (1) to $\check{V}st(r)$ as well, the relationship of weak clusters to English syllabification is evident.

In a strictly formal sense, Chomsky and Halle eschew direct reference to syllable weight. In fact, they concede (1968, 241, note) that the appearance of the context (1) in at least four different rules indicates a defect in their theory. But there is a possible remedy to this in a notation they adopt earlier just for expository convenience. They use W to indicate (1) considered as a single unit in phonological rules.

We could develop this idea into a theory in which languages can define certain strings as heavy or light syllables, allowing repeated reference to syllable weight at little formal cost. But this putative theory makes very weak claims. It says nothing about the

attraction of stress to heavy syllables nor about the equivalence of long to closed syllables. It allows free dependence of syllable weight on arbitrary segmental features. Finally, if we permit structural descriptions like S , meaning "a syllable, if it is light"
$$\langle L \rangle$$
(Welden (1977)), then we are treating these new units like phonological features, effectively allowing an unlimited set of features.

0.4. Moras

The Prague school mora (Trubetzkoy (1969); Jakobson (1971a)) is an abstract property of syllables. Syllables themselves are not exhaustively parsed into moras—rather, the mora measures the weight of a syllable. A light syllable is associated with or contains one mora, a heavy syllable two moras, and syllables of greater weight three or presumably more moras (Lecerf (1974)). A closed syllable with a short vowel (CVC) is monomoraic or bimoraic, under language-particular conditions.

The utility of this theory is well known to students of meter: it explains the common substitution of a heavy syllable for two light syllables and the converse (de Chene (1977)). Its application to accentual systems is specific to fixed demarcative stress (Jakobson (1971b)). In the general case, this type of stress assigns an accent some number n of moras distant from a boundary unit (for Latin, Jakobson (1971b); for Greek, Jakobson (1971c)) or from another accent (for Southern Paiute, Sapir (1930)). As long as n is small—perhaps one or two moras—it is unlikely that bimoraic syllables will be skipped over in accentuation.

This is certainly an attractive result, but the moraic theory has a serious lacuna. Many languages (like Classical Arabic, described below) attract stress onto a heavy syllable regardless of the remoteness of a boundary. The unboundedness of this phenomenon prevents a mora-counting solution, but the attraction of stress to heavy syllables is still displayed. The moraic theory, then, though explanatory in one class of examples, fails to make a prediction in another, related class.

My alternative proposal is based on the metrical theory of stress in Liberman and Prince (1977), together with some of the conceptual apparatus of the Prague school. It offers a mostly formal account of the same problems with which these earlier treatments were concerned. In what follows, I draw on Liberman and Prince (1977) and unpublished work by Paul Kiparsky, Morris Halle, Alan Prince, and Jean-Roger Vergnaud. Empirical justification and illustration come from the synchronic and diachronic description of Classical Arabic and some eastern Arabic dialects, though other phenomena are occasionally alluded to.

1. Cairene Colloquial

Perhaps the most interesting accentual phenomena of Arabic are found in a dialect spoken in Egypt from Cairo northward. Harrell (1957) gives three principal stress rules

for this dialect, along with a few morphological exceptions:[1]

(2) a.   Stress the ultima if it is a superheavy syllable (CVCC or CVVC):
        katábt ʿI wrote', sakakíin ʿknives'

    b.   Otherwise stress the antepenultimate syllable if the antepenult and penult
        are light syllables (CV), unless the preantepenult is also light:
        búxala ʿmisers', muxtálifa ʿdifferent (f. sg.)'

    c.   Otherwise stress the penultimate syllable:
        martába ʿmattress', ʕamálti ʿyou (f. sg.) did', béetak ʿyour (m. sg.) house',
        katabítu ʿshe wrote it (m.)'

This rule offers several notable peculiarities to an investigation of the relationship between heavy syllables and stress.

First, there is some evidence of a ternary syllable weight distinction. Word-internally, the stress rule contrasts light syllables (CV) with heavy syllables (CVC or CVV). Word-finally, stress lodges on a superheavy syllable (CVVC or CVCC), but a word-final CVC syllable fails to attract the stress: *mudárris* ʿteacher', *ʾábadan* ʿnever'. Although word-final CVV syllables are always stressed—*nisű* ʿhe forgot him', *šafúu* ʿthey saw him'—I argue later that this is due to other properties of the derivation of these forms. In sum, there are two binary syllable weight distinctions, light versus heavy word-internally, and light and heavy versus superheavy word-finally.

Second, there is a Janus-like aspect to (2b). It stresses the antepenult, but it must also take note of the weight of both the preceding and the following syllables. Ordinarily, stress rules are sensitive only to conditions exclusively to the right or the left of the focus.

Third, perhaps the most notable characteristic of this dialect is the rejection of stress by heavy antepenults: *martába* ʿmattress', *yiktíbu* ʿthey write', *mudarrísit* ʿteacher (f. construct)'. Since stress can go as far back as the antepenult, and since heavy syllables *are* stressed in penult position, this treatment of heavy antepenults is genuinely anomalous. It goes exactly counter to the universal tendency of stress assignment described in the introduction.

If that were all, then we might simply be compelled to accept occasional deviations from the attraction of stress to heavy syllables. Fortunately, though, additional data suggest a subtle realignment of the relationship of stress to syllabification. The examples in (2) exhaust the possible arrangements of heavy and light syllables in words of the Cairene dialect. But Classical Arabic words have a much richer set of canonical patterns, allowing very long strings of light syllables. Since there is no pandialectal tradition for stressing Classical Arabic, in many regions the colloquial stress rule is applied to Classical Arabic forms.

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[1] In the transcription followed here, ʕ and *ḥ* are voiced and voiceless pharyngeal glides, respectively. A subscripted dot indicates emphatic (velarized or pharyngealized) pronunciation. From the outset, I adopt a bimoraic representation of long vowels, anticipating the discussion in section 3. Many irrelevant shadings of vowels are not indicated.

Mitchell (1975) reports the pronunciation of a large number of Classical Arabic words by two Egyptians educated in Cairo.[2] Their treatment of words with the same canonical pattern as those in (2) shows that the Cairene rule holds as well for their pronunciation of Classical Arabic:

(3) a.   darábt 'I/you (sg.) beat', hajjáat 'pilgrimages'
    b.   kátaba 'he wrote', ʔinkásara 'it got broken'
    c.   qattála 'he killed', katábta 'you (m. sg.) wrote', haaðáani 'these (m. du.)', faʕalátun 'deed (nom.)'

So the accentuation of Classical Arabic words is another source of information about the form of the Cairene stress rule.

By Harrell's formulation in (2), we expect (2c) to give penult stress whenever the penult, antepenult, and preantepenult are light, like *katabítu*. Classical Arabic words with longer strings of light syllables than *katabítu* sometimes observe (2) and sometimes do not:

(4) a.   Observe (2):
          šajarátun 'tree (nom.)'
          šajaratuhúmaa 'their (du.) tree (nom.)'
          ʔadwiyatúhu 'his drugs (nom.)'
    b.   Violate (2):
          šajarátuhu 'his tree (nom.)'
          ʔadwiyatúhumaa 'their (du.) drugs (nom.)'

Clearly, Harrell's rule does not extend to forms like those in (4b).

Mitchell never formulates a uniform rule to stress these words, though he does give a thorough list of canonical patterns. On the basis of these, we can extract some coherent generalizations (Langendoen (1968)):

(5) a.   Stress a superheavy ultima.
    b.   Otherwise stress a heavy penult.
    c.   Otherwise stress the penult or antepenult, whichever is separated by an even number of syllables from the rightmost nonfinal heavy syllable or, if there is no nonfinal heavy syllable, from the left boundary of the word.

This rule covers all of Harrell's cases and Mitchell's as well. (5b) stresses the penult in, say, *ʕamálti*. Under rule (5c), *búxala* contains no heavy syllable, so we begin counting parity at the left boundary of the word. The antepenult then receives the stress because zero syllables—an even number—separate it from the left boundary. The preantepenult

is the rightmost heavy syllable of *ʔinkásara*, and zero syllables separate it from the antepenult, which then receives the accent.

Though this may seem a bizarre rule, formally similar stress rules are not all that uncommon. I am aware of two others. The stressing of some forms in Plautine Latin is one such example, described in section 5. Another is the tonal accentuation of Creek words without inherent accent. Haas (1977) presents the following data:

(6) a.   sókca 'sack', pocóswa 'axe'
     b.   hátkii 'white', hoktíi 'woman'
     c.   ifá 'dog', ifóci 'puppy', amifocí 'my puppy', waakocí 'calf', alpatóci 'baby
           alligator', iŋkosapitá 'one to implore'

The forms in (6a) show stressing of a heavy penult when the ultima is light. Heavy ultimas apparently induce morphologically-governed accentuation, as in (6b). For examples like (6c), Haas formulates a principle that I will informally paraphrase as: accent the penult or ultima, whichever is separated by an odd number of syllables from the rightmost nonfinal heavy syllable or the first syllable.

Both the Cairene and the Creek rules show that the relationship between syllable weight and stress or accent assignment can be quite subtle. Notice that these rules combine properties that, separately, are all reasonably familiar. The search for a rightmost (or leftmost) heavy syllable that terminates at word-boundary is common; in fact, Classical Arabic is an example of it, as I show in section 4.3. The feature of parity-counting, distinguishing odd from even syllables or moras, is characteristic of, say, Southern Paiute. Finally, the limitation of stress to one of the last two or three syllables in the word corresponds closely to the Dreisilbengesetz of Classical Latin.

Some of the theories outlined in the introduction propose explanations for one or another of these properties. For instance, the tendency to stress heavy syllables explains why a rule might seek the rightmost heavy syllable. If this tendency is thwarted by the absence of a heavy syllable, the rule defaults to the last syllable it sees. But rules of the Cairene type seek that syllable not to stress it but rather to begin again with a whole new procedure. So this tendency makes no prediction here.

Another case of this is the phenomenon sometimes called a law of limitation. In demarcative stress languages, we can speak of a law that governs the maximum distance between the stress and the word-boundary. The Classical Latin Dreisilbengesetz, limiting stress to the last three syllables, is a good example of this. Rules of this sort have received the most attention from the Prague school. This theory takes the limitation to be an effect of counting syllables or moras from the boundary. In particular, mora-counting should explain disjunctions of the sort "accent a heavy penult, otherwise the antepenult". But again rules of the Cairene type defy this simple account; the stressing of penult or antepenult depends both on their weight and on the weight of other syllables to the left. In this case, then, the mora-counting solution explains only part of the rule.

Evidently, stress rules of the Cairene type are inexplicable under two theories that

offer a connection between stress and syllable weight. Only the theory that makes the weakest claims, the formalism of Chomsky and Halle (1968), can overcome the vicissitudes of these accent rules. Consider the following formulation of clause (5c) of the Cairene stress rule:[3]

(7)   V → [+stress] / # (Q V [+seg]) (CVCV)$_0$ C _____ (CV) CV ([+seg]) #

Although this rule is quite complex, its mode of application is reasonably perspicuous. The first parenthesized term selects the rightmost heavy syllable if there is one. The second parenthesized term skips over the largest possible even number of light syllables. Material after the focus selects the antepenult or otherwise the penult.

The formal complexity of (7) does have some consequences. Chiefly, it claims that rules of the Cairene type are much less highly valued than rules that just seek a rightmost heavy syllable, that count parity, that stress the penult or antepenult, or that combine two of these properties. This claim is quite difficult to verify, but at least we have seen that the Cairene rule is scarcely a unique exponent of its type. A far more serious objection depends on a form of argument developed by Anderson (1974) in his discussion of the parenthesis-star notation. Notice that the material in the second set of parentheses—CVCV—exactly duplicates the material in the focus and immediately adjacent to it. In other words, this notation requires the duplication of information about adjacent light syllables. Though this is not an intolerable consequence, it certainly adds to the faults of this theory already described in the introduction.

2. Metrical Phonology

A different solution to Cairene stress not only eliminates these assorted problems but also leads to an explanatory model of the relationship between stress and syllable weight. The basis of this solution is Liberman and Prince's (1977) metrical theory of phonology. I will further assume a suggestion made by Alan Prince in unpublished work that the feature [stress] be eliminated. Therefore, all stress information is encoded directly in the metrical trees, and the stress rules of a language are simply rules for the geometry and labeling of metrical trees.

In Liberman and Prince's (1977) model, a tree that handles the Cairene accent should have the following characteristics:

(8)   a.   Binary feet are assigned from left to right to pairs of light syllables. That is:

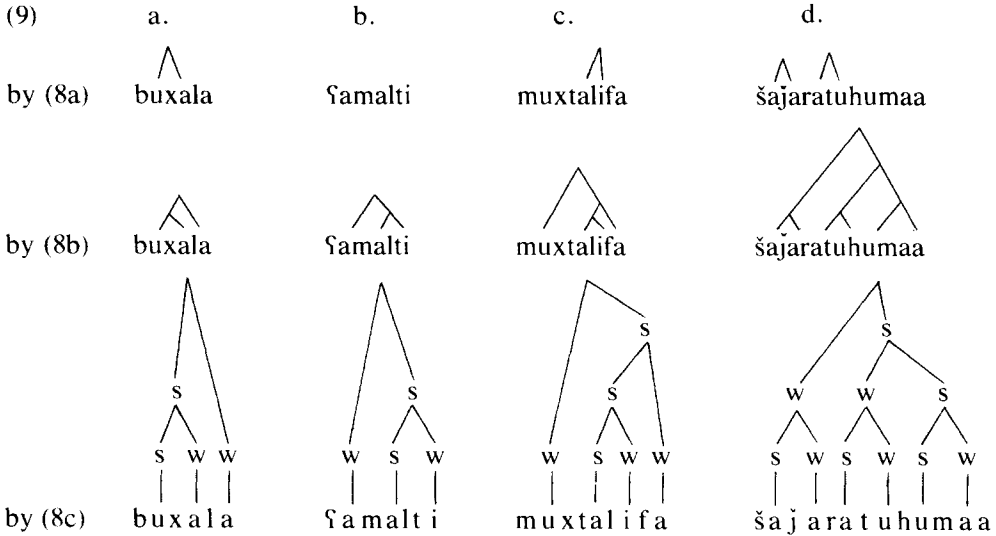... H L L L L L ... or # L L L L L ...
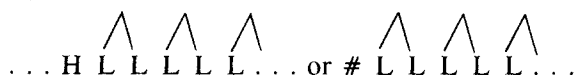
   b.   A right-branching superstructure gathers up all feet and stray syllables in the word.

[3] A similar version is given by Langendoen (1968). Welden (1977) offers a formulation of this rule in terms of syllables, where syllable weight is referred to by the feature-like notation described in section 0.3.

c.   The entire tree is labeled according to the principle that a right node is
   strong (s) if and only if it branches.

If the tree is assembled in this way, then the designated terminal element (the terminal
node of the tree that is dominated only by *s*s) will mark the stress-bearing syllable.

On some typical examples, the informal stages of tree construction are:

(9)   a.   b.   c.   d.

by (8a)   buxala   ʕamalti   muxtalifa   šajaratuhumaa

by (8b)   buxala   ʕamalti   muxtalifa   šajaratuhumaa

by (8c)   buxala   ʕamalti   muxtalifa   šajaratuhumaa

Note that the heavy penult of *ʕamálti* and the heavy ultima of *šajaratuhúmaa* cannot
be assigned to feet by (8a), which applies only to light syllables. They instead receive
metrical structure only from the right-branching word-level tree.

Example (9d) independently confirms the exact nature of the stress tree. Mitchell
reports an overall pitch pattern for this word of the following form:

(10)   —

        ša   ja   ra   tu   hu   maa
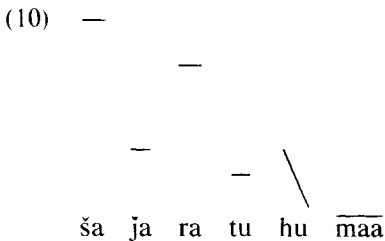
There is a general downdrift across the word, and a sharp fall on the stressed syllable.
But the syllables *ša* and *ra*, which are each locally more prominent, have higher pitch
than their sister constituents. This is evidence, then, that foot-level prominence relations
play some role in the pitch contours within words.[4]

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[4] Welden (1977) presents quite extensive data on secondary stress with some surprising properties. But
facts described independently by Harrell (1960, 10) and Abul-Fadl (1961, 241) contradict much of her data.
These latter authors both ascribe secondary stress to every heavy syllable that is not primary-stressed. This
is presumably a result of some late phonetic adjustment unrelated to the metrical trees.

Some of the advantages of the solution outlined in (8) are already apparent, although it still awaits formalization. First, the parity-counting is stipulated once and for all by a single rule of foot assignment. Second, it is unnecessary to refer to a disjunction of rightmost heavy syllable and left word boundary. Instead, the left-to-right assignment of feet applies whenever (8) finds adjacent light syllables. Third, the stressing of heavy penults is brought under the same rubric as the other syllable patterns.

But although rule (8) works correctly in the vast majority of cases, there are two sets of apparent exceptions to it. One involves the stressing of superheavy ultimas; this will be dealt with shortly. The other class of exceptions is under morphological government. If a third person feminine singular verb is followed by a pronominal object clitic, the accent falls on the feminine inflectional suffix: *kallim+ít+ak* 'she spoke to you (m. sg.)', *ram+ít+u* 'she threw it (m.)'. The expected stressing of these words by rule (8) is **kallímitak* and **rámitu*. If these forms appear without the pronominal clitic, the stress is as expected: *kallímit, rámit*.

The metrical tree notation permits an explanatory but very restrictive account of this exception. A morphologically-governed rule creates a branching node over the verbal suffix +*it* and any following material:[5]

(11) $\quad$ +it+X $\qquad\qquad$ /\\
$\qquad$ 1 $\;$ 2 $\;\Rightarrow\;$ 1 $\qquad$ 2

If the variable X is a null string, then the branching node will simply not be created by rule (11), since inherently the tree notation only expresses relations between nonnull elements. If X is nonnull, then rule (8) will follow (11), correctly assigning the remainder of the metrical structure to this word, and labeling the entire tree. No conflict between the two rules of tree assignment is possible since the notation does not allow overlapping trees, giving precedence to the earlier rule.

This natural treatment of exceptionality within the metrical theory explains why +*it* is stressed only when it is followed by other material. It also restricts or orders the possible exceptions. For instance, if +*it* always induced final stress in **kallimiták*, **ramitú*, then rule (11) would need to create labeling as well as structure. The labeling of these exceptional forms comes from a general rule of the phonology.

3. Syllabification

It is a somewhat different matter to incorporate into these rules the stressing of the ultima, an issue that leads to a formal treatment for heavy syllables. I will first review the facts of final stress. A superheavy (CVVC or CVCC) ultima is always stressed. A light or a closed heavy (CVC) ultima is not stressed: *ʕamálti* 'you (f. sg.) did', *madáaris* 'schools'. Given the parallel behavior of CVC and CVV syllables word-internally, we might expect them to behave alike word-finally. Confusingly, an open heavy (CVV) ultima is always stressed in colloquial words but unstressed in Classical Arabic words

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[5] A similarly anomalous penult stress occurs in plural nouns like *sibíta* 'baskets' or *dubúʕa* 'hyenas'. Apparently a rule like (11) is associated with this plural morphology.

that are otherwise stressed in conformity with the colloquial pattern. The solution to this evident inconsistency comes from an examination of the source of stressed CVV ultimas in the colloquial.

With only rare exceptions, stressed word-final CVV syllables are the surface reflex of a third person masculine singular objective or genitive suffix on a verb, preposition, or noun: *ramáa* 'he threw him', *ʔaxúu* 'his brother'. Actually, these forms have super-heavy final syllables at a more remote stage of the derivation, and so are stressed regularly.[6] Besides maintaining the parallel between CVV and CVC syllables, two other arguments support this position.

First, all these forms with a stressed final long vowel are in stylistically-conditioned variation with forms with final *h*: *ramáah, ʔaxúuh*. The forms with *h* are apparently characteristic of slow or emphatic speech (Tomiche (1964); Harrell (1957)). Since *h* is invariant when part of the stem (e.g. *minábbih* 'alarm clock'), I follow Brame's (1971) suggestion for a similar phenomenon in a Levantine dialect and restrict deletion to suffixal *h*:

(12)   h → ϕ / [+$\overline{\text{suffix}}$] #

Brame presents an argument from this dialect that also carries over to Cairene. If a dative suffix follows the third person masculine singular object suffix, the *h* shows up overtly: *rama+hú+lha* 'he threw it (m.) to her'. Brame argues that this morpheme is subject to a metathesis rule, and I will assume that the same is true of Cairene. Since the full analysis would take us too far afield, I refer the reader to Broselow (1976, 130) for a version of this rule.

Pace deletion of final *h*, then, the problem is very simple to state: the final syllable is stressed if and only if it has the canonical pattern CVVC or CVCC. Since the final syllable is always the right daughter of any tree it is associated with, it should never be labeled *s* by (8c). Therefore, ultima stress is impossible under our present understanding.

But notice this one peculiarity of the canonical syllables CVVC and CVCC: they are possible syllables of Cairene only in word-final position. The maximal word-internal syllables are simple heavy CVV and CVC. Suppose minimally that syllables are associated (after Kahn (1976)) with simple syllabic trees:

(13)   σ   σ   σ
           /\   /|\   /|\
          C V   C V V   C V C

Each node σ is immediately and exhaustively dominated by a terminal *s* or *w* node of the stress tree generated by (8). In a way that we could easily further specify, the binary and ternary branching syllable trees of (13) exhaustively parse the segments of Arabic

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[6] Alternatively, CVV ultimas could be stressed by a morphological rule associated with the objective suffix. The very rare words like *gatóo* 'cake' and *hayáa* 'life' would then be costly positive exceptions to this rule. This nonphonological solution, while unnecessary in Cairene, seems appropriate to account for similar facts in Damascene Arabic.

words with one exception: the superheavy CVVC and CVCC ultimas. A new rule allows these strings to be parsed as well by Chomsky-adjoining a word-final consonant to a preceding heavy syllable:

(14)
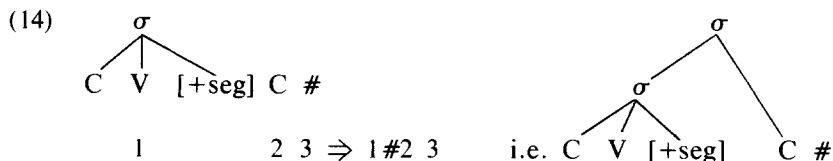
What rule (14) says is that a superheavy ultima is a syllable which also contains a heavy syllable as its left daughter. That heavy syllable—the subordinate σ of the derived structure—becomes in effect a heavy penult, since it is the second last major constituent in the word. It therefore is stressed like any heavy penult. I will show shortly how exactly to bring this about through the metrical formalism.

Rule (14) explains something about the weight of final syllables in Cairene. It also suggests that we might look further, into the syllables themselves, for further evidence of hierarchic structure. A proposal in this vein, first made and developed by Paul Kiparsky in class lectures,[7] is that each segment is the terminal node of a binary-branching tree of ss and ws, where the root is the syllable node σ. In conformity with the usual observations about syllable structure, relative prominence in the tree is mapped onto relative sonority of segments. Thus, the designated terminal element is the syllabic


nucleus, an obstruent plus sonorant cluster is C C, and so on. A specification of the possible syllabic trees, along with some language-specific conditions on the way in which they are associated with strings of segments, constitutes the syllabification rules of a language.[8] Note that this theory is entirely neutral with respect to questions of when syllabification occurs. I will, however, assume that strings are syllabified in underlying representation and successively after each stage of the derivation. This most strongly limits the derived structures of rules of epenthesis, syncope, and so on.

The special character of this treatment of syllabification is that it considers some substrings of syllables to be structural units. The adduction of evidence on this point depends on the following logic. Suppose we have some string of units hierarchically arranged with proper bracketing. Suppose further that all rules, or some class of rules, refer to the hierarchy. Then rules referring to nonconstituents will be more costly formally, and therefore less highly valued, than rules referring to constituents. For

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[7] A similar structure, though without labels, was proposed by Prince (1975).

[8] For further discussion of metrical structure inside syllables, particularly in segmental phonological rules, see McCarthy (1977; forthcoming).

instance, long vowels can have a bimoraic representation but also be associated with a
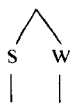
single metrical unit: $\overset{\displaystyle\underset{s\ \ w}{\bigwedge}}{\underset{V\ \ \ V}{\big|\ \ \big|}}$. Then any rule applying to this entire structure will affect both moras as if they were a single segment. I claim that all vowel length is represented in this way.

A very plausible constituent analysis within the syllable is the rhyme—the syllable nucleus plus any following vowel or consonant. In this notation, the rhyme is defined as the right branch of σ. Thus, the rhyme is the circled constituent in the syllable trees (15a–c):

(15) a. σ b. σ c. σ
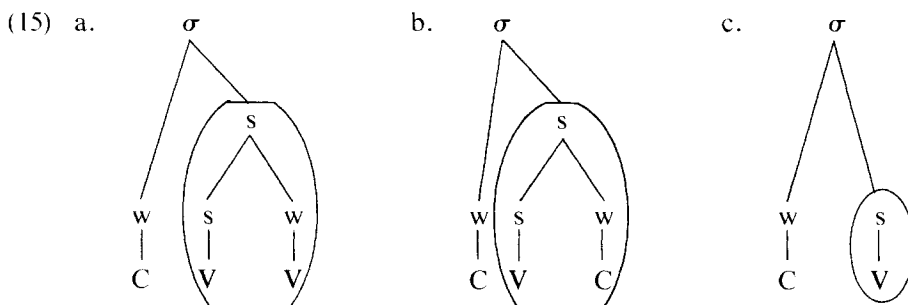
Evidence for this constituent is quite extensive, and is scarcely exhausted by the following list:

   i. In Lithuanian ''the accent may strike not only vowels but also postvocalic sonorants, provided that they belong to the same syllable as the immediately preceding vowels'' (Kiparsky and Halle (1977)). That is, the accent may lie on any nonobstruent within the rhyme.

   ii. Kahn (1976) argues that English vowels destress only if they are syllable final. That is, a vowel must exhaust the rhyme for destressing to apply.

   iii. Complementarily, the English pig Latin rule severs and postposes the syllable onset, the segments not in the rhyme.[9]

   iv. French vowels assimilate in nasality to following tautosyllabic consonants. Therefore, the rhyme is the domain of the feature [+nasal].

So the reality of a rhyme unit in many phonological rules is not difficult to establish, and we have a notation to express that reality. There is a good deal more to say about this, but first we need one other basic notion to allow a synthesis of syllable structure and stress.

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[9] I am indebted to Will Leben for pointing this out to me.

Vergnaud (ms.) proposes a theory of phonology in which all rules operate on projections—phonologically-defined sets of substrings—of strings of segments. For example, many vowel harmony rules apply to the projection of all [+syll] segments in a word. This idea can be fruitfully extended to the issue under consideration.[10] If segments are hierarchically arranged within syllables, as I have argued, then a projection rule could refer to individual segments or to some constituents of the syllabic tree. Thus, we can project all the vowels in a word or all the rhymes in a word or even all the syllables. If a language has structures like those in (15), then we cannot, except perhaps at great formal cost, project all CV sequences in a word. But in the particular case in which a rule projects all and only the rhymes in a word (where rhyme is defined as above, the right branch of σ), then syllable weight has an obvious geometric interpretation: heavy syllables branch, light syllables do not. Clearly, not all stress rules will project rhymes—some project every vowel or every syllable—but all must project a constituent of the syllabic tree.

With some further elaboration, this mechanism explains the asymmetry between CVV and CVC syllables. Recall the principle attributed to Trubetzkoy and Jakobson: a language treats CVC syllables as heavy only if it treats CVV syllables as heavy. So there exist languages that have CVV and CVC syllables where CVV is heavy but CVC is not. Two languages of this sort may be Yidin^y (Dixon (1977)) and Tiberian Hebrew (McCarthy (1979)). My proposal is that the syllable-structure repertory of these languages is as shown in (16):
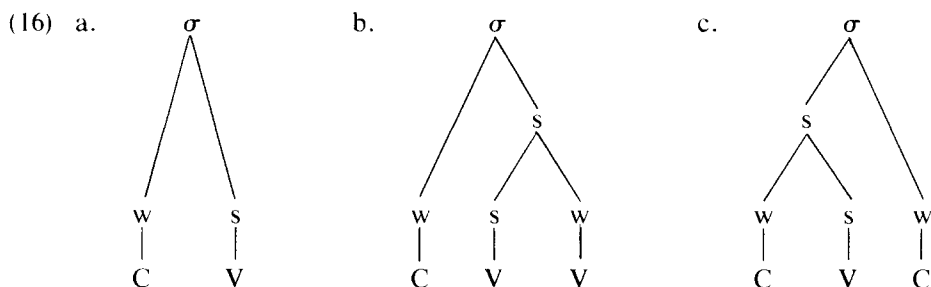
It follows that languages with syllabification like that in (16) do not have branching rhymes in CVC syllables, though they do have branching rhymes in CVV syllables, where rhyme is understood in the strict sense as the right branch of σ. The purely geometric account of syllable weight offered here will capture exactly this difference.

There is, of course, a complementary problem presented by Trubetzkoy and Jakobson's universal. We have to exclude languages with heavy CVC syllables but with light CVV or without CVV syllables. That is, we have to eliminate structural inventories

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[10] This suggestion is due to Morris Halle.

such as those shown in (17a,b):

(17) a.
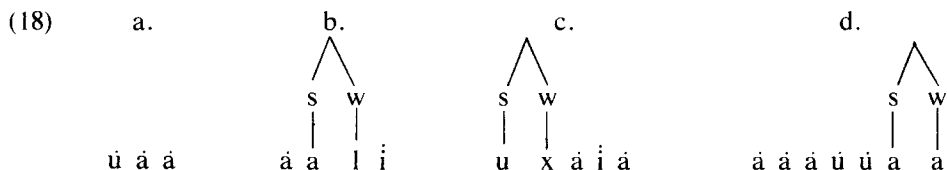
b.
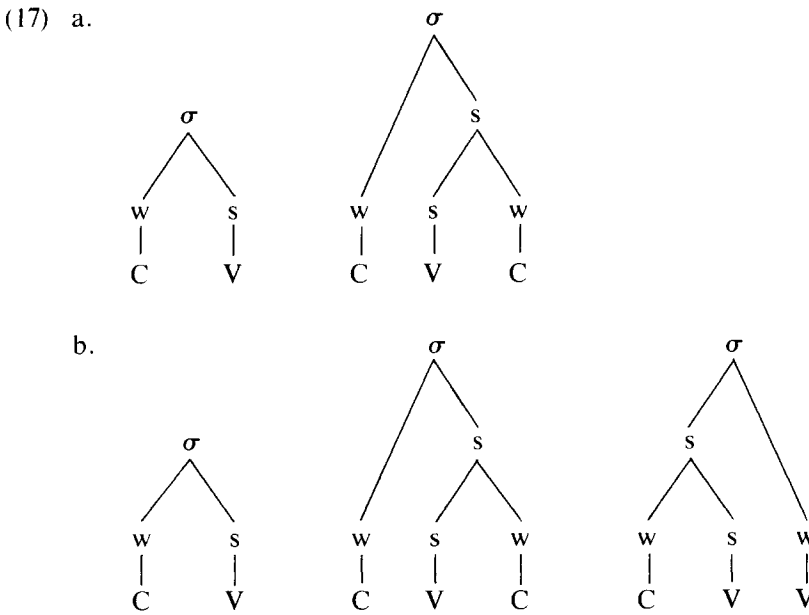
(17a) describes a language with heavy CVC syllables but without CVV syllables, while (17b) allows light CVV syllables and heavy CVC syllables. Not only should the theory exclude (17), it should also allow a principled choice between grammars with (16) and grammars with (15).

In fact, the theory of metrical syllabification does just this in a very natural way. Suppose that syllabification in general refers to only three parameters: the labeling of the rhyme, the branching or nonbranching character of the rhyme, and the major category features like [syllabic], [consonantal], and [sonorant]. Then the grammar of (15) must say only that weak rhymes (those labeled w) are forbidden. The grammar of (16), on the other hand, allows strong rhymes only if the segments in the rhyme are all [+syll]. Another possible grammar—for a language with (16a,b) but without closed syllables—also has [+syll] strong rhymes but prohibits weak rhymes. Still other languages may allow only rhymes with [−cons] segments or only rhymes with [+son] segments. Finally, a language with CV syllables exclusively prohibits branching rhymes entirely. But it is impossible under this theory to require that the two segments in a rhyme consistently *disagree* in some feature, so the structures in (17) are ruled out universally. Although other formal means of achieving this result suggest themselves, this one does make full use of the labeling and structures that are independently needed for the stress rules.

4. Exemplification
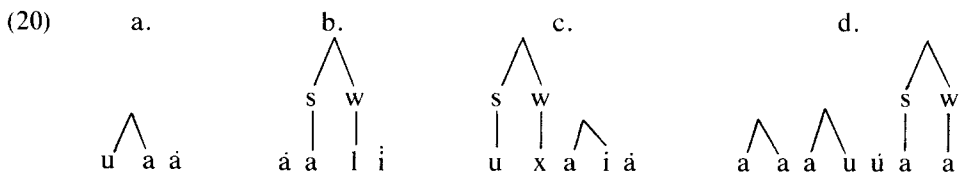
4.1. Cairene Colloquial

We can now explain some of the properties of the informal algorithm (8) for creating Cairene metrical structure. The first operation is to project all the rhymes of the word, yielding (18) from (9), for example:

(18) a. b. c. d.

```
                    s   w          s   w                       s   w
                    |   |          |   |                       |   |
    ú  á  á      á  a  I  i      u  x  á  í  á      á  á  á  ú  ú  a  a
```

Feet are formed over pairs of light syllables. This property is expressed by a formal condition on foot assignment in Cairene:

(19)   In a foot $[n_1 \ n_2]$, n_1 and n_2 do not branch.

I will stipulate that this assignment of feet is from left to right, yielding (20) from (18):

(20) a. b. c. d.

```
                    s   w          s   w                            s   w
                    |   |          |   |                            |   |
      u  a  á    á  a  I  i     u  x  a  i  á     a  a  u  ú  a  a
```

As a result of (19), the rhymes of heavy syllables and the feet have identical geometry. Finally, these structures are gathered together into a right-branching word-level tree.

The same projection mechanism applies to words with superheavy word-final syllables, though the results are a little different. Recall that superheavy syllables have a structure that includes two σ-nodes, as in (14). The rule that projects rhymes refers formally to "the right branch of σ", so in fact superheavy syllables contain two rhymes, and they will project as two units. For instance, the word *sakakūn* yields the following projection of rhymes:

(21)

```
              s   w
              |   |
    á  á  i   i  ń
```
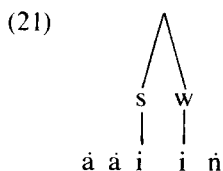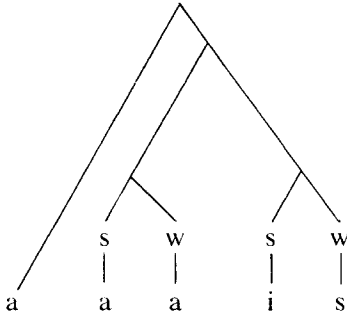
This is then geometrically equivalent to a word with a heavy penult, and receives stress in exactly the same way.

There is one remaining technical problem. Consider again a word like *madáaris*, with a heavy—though not superheavy—final syllable. The full metrical structure as-

signed to this word except for the labeling is:

(22)

Now if we attempt to label this tree by rule (8c), we will incorrectly get stress on the final syllable, since it is a branching node. The difficulty here is that rule (8c) treats the
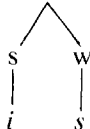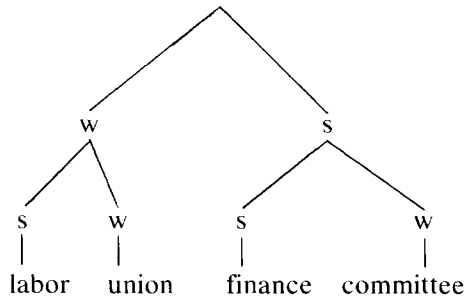

branching of syllable rhymes like *i*   *s* on an equal footing with the branching of foot- and word-level structure.

There is a clear precedent for a solution to this in Liberman and Prince (1977). Rule (8c) is identical to the labeling rule associated with compound words in English, as a few examples show:
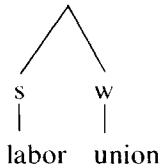
(23)   a.   b.

Now notice that the labeling of compounds is sensitive only to syntactic branching—it is unaware that *union* is a polysyllabic word and so has a branching word-stress tree. I will similarly claim that word-stress labeling rules (though not foot-assignment rules) are sensitive only to foot-level branching. Therefore, labeling cannot depend on whether a particular rhyme branches or not.[11]

4.2. *Damascene Colloquial*

The stress rule of the Damascus dialect (Cowell (1964); Grotzfeld (1965)) is a good deal more familiar than the Cairene one. Except for the Cairene-like stressing of superheavy

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[11] This suggestion is due to Alan Prince.

ultimas, it is identical to the Classical Latin stress rule: accent a heavy penult or the first syllable of a disyllabic word, otherwise accent the antepenult: [12]

(24) a. darrást 'I/you (m. sg.) taught', bət?úul 'you (m. sg.) will say'

b. fáthet 'she opened', madáares 'schools', šírib 'he drank'

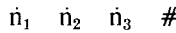c. dárasu 'they studied', mádrase 'school', muttáhide 'united (f. sg.)'

The final example is a loanword from Classical Arabic with a properly noncolloquial surface canonical pattern. It confirms the impossibility of retracting stress beyond the antepenult under any conditions.

Damascene is clearly subject to the same syllabification and labeling rules as Cairene. The real difference between Damascene and Cairene is foot construction. The Damascene stress rule, like that of Classical Latin, requires an equivalence between a heavy penult and an antepenult plus light penult. To see this formally, consider the rhyme projections of the crucial canonical patterns (abstracting away from the weight of the final syllable):

(25) a. heavy penult

$$
\begin{array}{ccc}
s & w & \\
| & | & \\
n_1 & n_2 & \dot{n}_3 \quad \#
\end{array}
$$
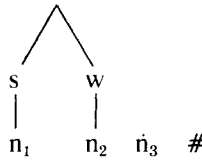
b. light penult and light antepenult

$$\dot{n}_1 \quad \dot{n}_2 \quad \dot{n}_3 \quad \#$$

c. light penult and heavy antepenult

$$
\begin{array}{cccc}
s & w & & \\
| & | & & \\
n_1 & n_2 & \dot{n}_3 & \dot{n}_4 \quad \#
\end{array}
$$
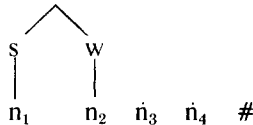
Suppose we then create a left-branching tree with the structure $[[n_1 \ n_2] \ n_3]$. This will yield the trees of (26), which, with subsequent assignment of right-branching word structure and labeling as in Cairene, give the correct stress:

(26) a.   b.   c.

$$
\begin{array}{ccc}
s & w & \\
| & | & \\
n_1 & n_2 & n_3
\end{array}
\qquad
\begin{array}{ccc}
 & & \\
 & & \\
n_1 & n_2 & n_3
\end{array}
\qquad
\begin{array}{cccc}
s & w & & \\
| & | & & \\
n_1 & n_2 & n_3 & \dot{n}_4
\end{array}
$$
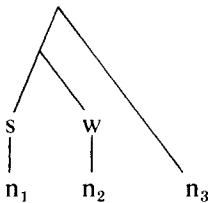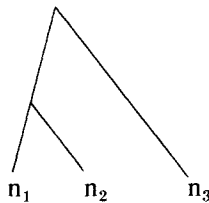
[12] This generalization has several morphological exceptions, most of which are handled by mechanisms similar to rule (11). For some discussion of these and possible cyclic metrical stressing in Damascene, see McCarthy (forthcoming).

The common property of these trees is that n_1 and n_2 are terminal nodes and therefore nonbranching, while n_3 can dominate a heavy or a light syllable.

The Damascene foot-assignment rule is expressed formally as (27):

(27) $[[n_1 \ n_2] \ n_3]$, where n_1 and n_2 do not branch.

I further stipulate that (27) applies from right to left, which will ensure in all cases that stress never recedes past the antepenult. The bracketing in (27) is interpreted as constructing a left-branching tree while preserving and usin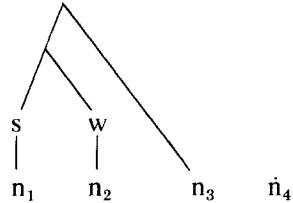g any preexisting metrical structure. In practice, if n_1 and n_2 are already sisters, then n_3 is right-adjoined to them. If they are not already sisters, then the full left-branching structure is created. (27) cannot destroy structure that was present before it applied.

There is a reason why both the Cairene and Damascene rules refer to nodes that do not branch. A nonbranching node in a projection of the rhyme is much like the Prague school mora. The real difference is that, while the mora was defined somewhat arbitrarily on a language-by-language basis, the equivalent notion in the metrical theory ties into a whole complex of formal properties of syllabification and accentuation. Furthermore, the metrical theory provides a natural account of stress rules that clearly do not count moras, like the following one.

4.3. Classical Arabic

The stress phenomena of Classical Arabic have a somewhat difficult provenience. The native orthoepists said nothing about stress in their usually detailed descriptions. Consequently, in most areas the colloquial stress rule is applied to Classical Arabic, as in Cairo. Chiefly for this reason, it is widely believed that Classical Arabic had no regular word stress (Birkeland (1954); Rabin (1978); Ferguson (1956)). But there is a stress pattern—the same one described in handbooks like Wright (1971)—that is traditionally observed in some areas despite the dialectal pronunciation. For instance, Abul-Fadl (1961) reports the following accentuation of Classical Arabic in an area where the Cairene and Damascene stress rules generally apply to the colloquial:

(28)   kitáabun 'book (nom. sg.)', manaadíilu 'kerchiefs (nom.)', yušáariku 'he participates', mámlakatun 'kingdom (nom. sg.)', kátaba 'he wrote', bálaḥatun 'date (nom. sg.)'

The rule usually formulated to account for these facts is (29):

(29)   a.   Stress a superheavy ultima.[13]
        b.   Otherwise stress the rightmost nonfinal heavy syllable.
        c.   Otherwise stress the first syllable.

In addition to the observance of (29) in some modern traditions, there are two other

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[13] Syllables of this type are limited to so-called pausal forms that occur before major syntactic breaks.

arguments for this rule in Classical Arabic. First, it has been retained in a few modern colloquials like the Egyptian Saˤiidi (Khalafallah (1969)) and Yemen Plateau (Diem (1973)) dialects. Second, there is some basis for inferring stress patterns from the system of rhyming in verse or rhymed prose (*sajˤ*). For instance, the difference between masculine and feminine rhymes in English or Modern Hebrew is just the difference between end-stressed and penult- or antepenult-stressed words. The Arab orthoepists recognized an elaborate typology of Classical Arabic rhyming. One type involves superheavy final syllables, another heavy penults, on through a heavy syllable that is the fifth back from the end of the word. In terms of (29), then, the rhyme in verse is just the string that includes the stressed vowel rightward to the end of the word.

So the Classical Arabic stress rule has one of the properties of the Damascene rule: it will not skip over heavy syllables. But Classical Arabic allows retraction of stress a potentially infinite distance from the right boundary, rather than the maximum of three syllables permitted in Damascene. This means that the Classical Arabic foot must also be of potentially infinite size. In all other respects it is like Damascene:

(30) $[[[\ldots [n_1 \ n_2] \ldots]n_{i-1}] \ n_i]$, where $n_1, \ldots, n_{i-1}$ do not branch and n_i is maximal.

This infinite schema, along with the stipulation that the foot be as large as possible, is all that separates Classical Arabic from Damascene. As in Damascene, feet are applied from the right, word structure is right-branching, and labeling follows (8c).

5. Diachronic Considerations

These evident similarities between the stress rules of Damascene and Classical Arabic certainly suggest an historical connection. In previous work, the issue has been clouded somewhat by the view that Classical Arabic was without word stress. So Cowan (1960), for instance, holds that the ancient ancestor of the modern dialects was without regular stress, and that the modern eastern stress patterns arose independently. My view is closer to the more traditional one of Brockelmann ((1961, originally published in 1907); more recently Janssens (1972)) that the phenomena in all the modern dialects should be related historically to a rule like (29). Apart from (29) I attribute no properties to a protocolloquial Arabic (Ferguson (1978)) that is distinct from Classical Arabic.

In the metrical analysis of Arabic stress that has been proposed here, the sole difference between Classical Arabic and Damascene Arabic is that the former has potentially infinite feet while the latter has reduced the foot to three nodes subject to the same conditions on branching. In fact, except for a few scattered dialects, no modern colloquial has feet of the indefinite-sized, Classical Arabic type. Now notice that this distinction seems to correlate with the existence of extensive vowel reduction (deletion of unstressed vowels in open syllables, sometimes restricted to nonlow vowels) in the same colloquials. If vowel reduction is—at least in its initial phonetic development—a reflex of stress timing, then we can see that the colloquials must be stress timed, while

Classical Arabic was not. Stress timing in a metrical theory can be understood as just timing of the duration of feet. If the feet are limited to two or three syllables, as in the colloquials, they can be easily, though not necessarily, stress timed. This is clearly not the case with the Classical feet. Potentially infinite feet are presumably unmanageable for a stress timing rule.

Probably the Damascene foot is the most common Arabic type: it seems to hold for much of the Levant and may also be prevalent in the western dialects, like Maltese (Brame (1973)). So apparently this reduction of the original potentially infinite schema to a fixed one with three terms was a fairly early development. But in Cairene we have just a two-term schema, where both nodes are nonbranching. My suggestion is that Cairene simply displays the loss of that third term n_3 from the rule schema, a formal historical rule simplification.

Unfortunately, Cairene presents one other historical problem that remains intractable. Feet must be assigned from left to right in Cairene but from right to left in the other colloquials and in Classical Arabic. This change in direction is entirely unexplained under the account offered here. The ideal explanation would be to posit a relationship between the form of the foot and the direction of its application, so the change in direction in Cairene would be automatic. Although no complete solution is forthcoming, some new evidence bearing on this question suggests that the form of the feet does partially or fully determine the direction of their assignment.

It is generally agreed (Sturtevant (1940)) that preclassical Latin was prototone: stress the initial syllable. The Classical Latin stress rule was like the Damascene rule we have already seen. In the paragraphs that follow are some conjectures toward explaining this historical change.

The only evidence of any intermediate historical stage comes from early Latin verse, where the correlation of metrical ictus and accent is supposed to show the position of stress (Fraenkel (1928)). In this material, quadrisyllabic words with the first three syllables light were often accented as in earlier Latin *fácilius*, sometimes as in Classical *facílius*, and rarely, though interestingly, *facilíus* (particularly before major constituent breaks). Trisyllabic words with heavy first and light second syllable are usually stressed like *córpore* in this verse, as in prehistoric and Classical Latin. But again, some examples occur before syntactic breaks with the accentual type *corpóre*.[14]

The evidence of ictus is apparently not sufficient to determine whether the acute marks primary or secondary stress in *facilíus* and *corpóre*. What is significant is that these two types are identical in effect to the Cairene stress rule. So in addition to initial stress, preclassical Latin apparently had a left-to-right foot assignment just like Cairene.

For reasons that I do not understand, the Latin foot was expanded historically from the Cairene to the Damascene type. To the point at issue, this change in feet seems to have automatically induced a change in the direction of foot assignment. It seems likely

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[14] For a discussion of these facts with a view toward explaining the retarded stress shift in forms like *fácilius*, see Allen (1973).

that left-branching feet, as in Damascene or Classical Latin, require right-to-left application in some way that this formalism fails to capture. Symmetrically, a foot which explicitly does not branch on the left, as in Cairene, may allow the opposite direction of application. Historically, the change in the Latin foot from binary to left-branching ternary required a shift to right-to-left application. The change in Cairene from ternary to binary feet at least allowed and may even have required a shift to left-to-right application. In short, these two languages had opposite historical accentual developments.

6. Conclusion

The model of metrical syllabification presented here was chiefly justified by its success in accounting for a wide variety of accentual phenomena. It raises some new issues as well. First, there is the question of universal constraints on the form of foot-assignment rules. We have seen that several different nodes of the foot can be stipulated as nonbranching or freely branching in different languages. We have also seen feet with two, three, and an unbounded number of nodes. Some efforts toward restricting the geometrical possibilities for feet are made in McCarthy (1979). Second, the theory predicts strong correlations between syllable weight and other phenomena. In particular, it says that the hierarchical units motivated at different levels by accentual facts ought to function in many other phonological rules as well. It remains to integrate these structures fully into the segmental phonology.

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