Comments and questions are welcomed. Critical comments, in particular, are solicited.
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Variation in word prosody of some dialects of Arabic; stress does not 'float'*

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The systems for assigning word stress in 4 closely related Arabic languages will be analyzed: Cairene Arabic, Palestinian Arabic, Negev Bedouin Arabic, and Cyrenician Bedouin Arabic (CBA). The section on of CBA, Section 6, is by far the longest and most important section.

The main goal of this paper is to give evidence that the idea of 'floating stress' is not only theoretically dubious, but unnecessary. One of the first instances to be discussed in the literature of what came to be called 'stress shift' was from Bani-Hassan Arabic, which was analyzed in Irshied and Kenstowicz (1984). Underlying *sahabatak* produces surface *shà.bá.tak*. This stress pattern is anomalous. In general, sequences of light syllables are grouped into binary feet from left to right. Since stress is trochaic, *(shá.ba)tak* is expected. Irshied and Kenstowicz proposed that the foot structure was created before vowel deletion, so that deletion operated on *(sa.ha)(ba.tak)*, yielding (after vowel deletion and resyllabification) *(sha)(ba.tak)*, with the foot structure preserved. The surface stress pattern is then explained if stress is computed on this structure, with trochaic foot stress and the rightmost foot stress enhanced to main stress.

Halle and Vergnaud (1987, p. 29) viewed the phenomenon differently: "when a stressed element is deleted … the stress of the deleted element will not be lost but will be transferred …". This introduces the idea of stress shift, which is quite different than the view of Irshied and Kenstowicz. For the latter, no stress is assigned before deletion, so there is nothing to shift. In spite of the statement by Halle and Vergnaud quoted above, they later in the same book seem to agree with Irshied and Kenstowicz. Halle and Vergnaud (1987, p. 140) is quite clear, although apparently contradictory to their earlier statement.

> … the construction of metrical constituents is effected in two stages, by means of two independent rules. … empirical evidence of the independence of the two components of metrical constituent structure is provided by such languages as Yidiny, in which the placement of heads, but not that of [foot] boundaries, is influenced by rules of the phonological component … (p. 149)

Kenstowicz (1994) switched to a stress shift analysis of these phenomena. He relies on the idea that stress is assigned prior to vowel deletion, then finds the appropriate 'docking

* Thanks to David Odden for a careful (and contentious) reading of an earlier draft.

site' after vowel deletion and resyllabification. There is some inconsistency, or at least the threat of inconsistency, because he also said that "... stress is not properly speaking a feature analogous to [nasal] or [voiced] but rather an abstract relation of prominence." That is, it is not like features which can float. Can 'abstract relations of prominence' float? McCarthy (2008) is quite clear that in his view phonological relations cannot float. He says "stress cannot float because it is a phonological relation rather than a phonological object, like a tone."

The longest and most important section of this paper, Section 6, is an analysis of Cyrenician Bedouin Arabic (CBA) word stress. CBA poses severe problems for the idea that stress floats when the prosodic entity it projects is deleted. It has vowel deletion operations that can delete all the vowels of the syllables in a foot, leaving a string of unsyllabified consonants. On the one hand, it seems that surface stress depends on the pre-deletion metrical structure. On the other, it seems that the metrical structure is destroyed by vowel deletion. What survives? Hayes (1995) offered a floating stress solution to the puzzle, but it is only barely plausible, although technically successful. It is discussed in Section 6. More importantly, it will be proposed that the metrical structure is not as disrupted as it might seem if syllabification is properly analyzed. Foot structure survives, not stress, which is not assigned until late in the derivation.

I proceed by first examining how the theory applies to Cairene Arabic. This goes over some well-known ground and is intended only to familiarize the reader with the technical details of how derivations are computed in the theory. McCarthy's (1979) analysis of Cairene Arabic was one of the founding papers of the modern theory of metrical word stress, so it is fitting that, after outlining the theory, we begin there. Other well-known transformational analysis are Halle and Vergnaud (1987) and Hayes (1995).

Next, the Palestinian variation of Cairene is analyzed and shown to be a minor variation.[1] The notion of 'extrametrical foot', crucial in Hayes (1995), is eliminated. Negev Bedouin Arabic is then shown to have exactly the same foot formation rules as Palestinian, but with iambic stress assignment. This brings us to CBA, which has the same foot formation rules as Palestinian and Negev Bedouin Arabic, and also assigns stress iambically, just like Negev Bedouin Arabic. The focus there is on understanding syllable formation. Properly understood, the effects of vowel deletion on stress patterns follows without any need for floating stress.

1. Variation here is used only as a comment about the relation of rule systems. No implication of diachronic development is intended.

Section 1. Preliminaries

Before Idsardi, it was common to view footing a word as the application of a 'parsing algorithm' which used some standard foot shape, or narrow range of foot shapes, to break the word up into feet of that shape. Idsardi's proposal changed this view. First, the vague notion of algorithm was abandoned in favor of a return to more standard phonology, an ordered sequence of rules. Of course, an ordered sequence of rules is an algorithm, but not in the shapeless form that had been suggested. Second, the notion of 'standard foot shapes' was abandoned. The foot shapes did not drive the rules, the foot shapes were what delimiter insertion produced.

Central to Idasrdi's approach was a new approach to grouping. The idea was that the fundamental operation was not 'form group', but 'insert delimiter'. There were two kinds of delimiters, one which marked the beginning of a group and one which marked the end of group; '$\langle$' and '$\rangle$'.[2] He noted that (1a) specified the grouping (1b) perfectly well, under the obvious interpretation of what 'same group' means in (1a).

(1) a. $\times\ \times\rangle\times\ \times\rangle\times$

b. $(\times\ \times)(\times\ \times)\times$

Using this idea, the notion 'footing algorithm' could be replaced by an ordered sequence of rules, each of which inserted a delimiter.

CWP proposes a more restrictive notion of delimiter insertion rule than originally proposed by Idsardi, both bringing delimiter insertion rules into a form more like other phonological rules and giving a framework for understanding locality. There are 4 primitive delimiter insertion rules (primitive DIRs). Each inserts a foot delimiter adjacent to the target beat.

$$\times \to \times\rangle,\quad \times \to \langle\times,\quad \times \to \times\langle,\quad \text{and}\ \times \to \rangle\times$$

Delimiter insertion rules in general have the form

(2) *primitive DIR* / *structural condition* ; *derivational constraint*

where the structural condition and derivational constraint are conditions which beats may or may not satisfy. They are assumed to be highly local, depending only on the beat being evaluated and the beats which flank it. The rule is applicable to a beat $\times$ if $\times$ satisfies the structural condition and the result of application would not produce beats which violate the derivational constraint.[3]

2. In an LR system, $\langle$ opens a group and $\rangle$ closes a group. The effects are reversed in an RL system.

3. More precisely, the beats which would flank the inserted delimiter would both satisfy the derivational constraint. The rule is is therefore highly local. See Section 3 in Frampton (2023, p. 6) for a careful discussion of locality.

For example, the DIRs (3a,b) below appear in many LR stress systems. *Uny is satisfied by a beat if it is not in a unary foot, i.e. one with a single member.[4]

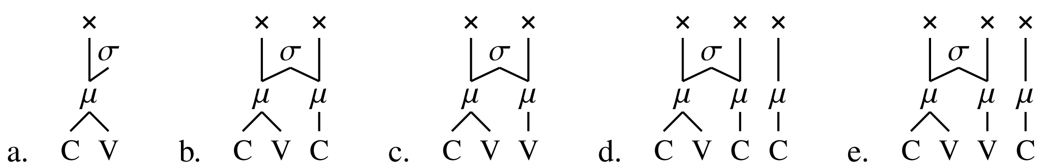
(3) a. × → ⟨× / #__ ; *Uny b. × → ×⟩ ; *Uny

(3a) is called $GF_{\#}$ (Group Forward, starting at the left edge). *Uny prevents $GF_{\#}$ from applying to a word with a single beat and from applying to to #×⟨×⋯. (3b) is called GB (Group Backwards).

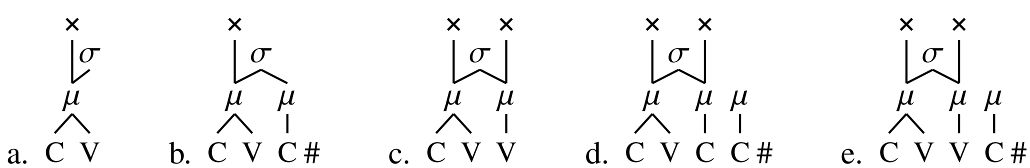
Section 2. Cairene Arabic

I have avoided to this point saying what line of 'entities' (i.e., beats) are subject to grouping/footing because the theory can accommodate various proposals. But to proceed, something more concrete is needed. I will assume that there is a line of beats which is projected from either the line of moras or the line of syllables; either a 'mora-counting system' or a 'syllable-counting' system. Cairene Arabic is mora-counting.

Arabic is generally thought to have syllable types CV, CVC, CVV, and what are called 'super-heavy' syllables CVCC and CVVC. The initial consonant can be empty; onsetless syllables are possible. I will assume that this describes the configurations (4), where moras project to beats. I assume that 'super-heavy' syllables are actually heavy syllables followed by an unsyllabified moraic consonant, allowed word-finally. I will return to this assumption later and discuss syllabification in some detail.

(4)


Cairene Arabic has what is called 'final consonant extrametricality'. I take this to mean that beats projected from word-final consonantal moras are deleted.[5] Deletion occurs prior to the delimiter insertion rules, so what the rules see is (5).

(5)


4. More precisely, we say × is *directly footed* if it is in the environment / __⟩ or the environment / ⟨__. A beat satisfies *Uny if it is adjacent to another beat or it it is not directly footed.

5. Alternatively, it could be assumed that final consonantal moras do not project in the first place. I think there are reasons to assume that it is deletion, but either assumption suffices for this paper.

In mora-counting languages, the rules can be sensitive to the pairing of two beats which are projected from the same syllable. Beats which are projection of cosyllabic moras will be called cosyllabic beats. I use ‿ as a diacritic on the beat line to indicate cosyllabicity of the flanking beats. (5) illustrates this notation. The footing and stress is McCarthy's proposal. There is a single surface stress, located on the lefthand syllable (trochaic stress) of the rightmost foot. All the examples are from McCarthy (1979).

(6)	a.	*mu.dár.ris*	× (×́‿×) ×	'teacher'	p. 446
	b.	*ʔá.ba.dan*	(×́ ×) ×	'never'	p. 446
	c.	*ni.síː*	× (×́‿×)	'he forgot him'	p. 446
	d.	*ša.fúː*	× (×́‿×)	'they saw him'	p. 446
	e.	*sa.ka.kíːn*	(× ×)(×́‿×)	'knives'	(2a)
	f.	*ka.tábt*	× (×́‿×)	'I wrote'	(2a)
	g.	*bú.xa.la*	(×́ ×) ×	'misers'	p. 446
	h.	*mar.tá.ba*	(×‿×)(×́ ×)	'mattress'	p. 446
	i.	*yik.tí.bu*	(×‿×)(×́ ×)	'they write'	p. 446
	j.	*mu.dar.rí.sit*	× (×‿×)(×́ ×)	'teacher (f. construct)'	p. 446

Delimiter insertion rules for generating this grouping pattern are given (7). It follows Idsardi in assuming that in general there are two kinds of delimiter insertion rules. One is non-iterative and inserts a delimiter in a local relation with an edge or in a local relation with a landmark that can be identified in the unfooted form, typically beats projected from heavy syllables.

(7)
$$\left.\begin{array}{l} \times \rightarrow \langle \times \;/\; \_\_\smile \times \\ \times \rightarrow \langle \times \;/\; \#\_\_ \\ \left[\, \times \rightarrow \times \rangle \,\right]_{LR} \end{array}\right\} ;\ {*}\text{UNY} \qquad \begin{array}{l} (GF_{H}) \\ (GF_{\#}) \\ (GB) \end{array}$$

The iterative rule is applied LR. More precisely, say that a beat × is a current target if the iterative rule is applicable to × and is not applicable to the beat left-adjacent to ×, if there is one. The iterative rule applies to the current targets.

Below are full derivations of some of the words in (6). Doubled foot delimiters indicate delimiters inserted by the marking rules. This is for the reader only, the grammar does not distinguish between delimiters inserted by marking rules and those inserted by the iterative rule. The horizontal line separates the applications of the marking rules and the iterative rule. Beats to which a rule has already applied are notated by an 'under asterisk'.[6] They are inactive and cannot be the target of another delimiter insertion rule. See Section 4.3 in Frampton (2023) for a discussion of what was then called the Once and Done Principle; now called the Free Beat Condition (FBC). The current targets are notated with a cursor. These (in an LR system) are the active beats which do not have an active beat on their left.

6. I assume that the iterative rule applies to every beat it targets since it does always alter the current representation, at least by moving the cursor.

A cursor is not relevant until the marking rules have applied and the directional iterative rule is ready to apply.

(8)	a.		*sa.ka.kiːn*	b.	*mu.dar.ris*	c.	*mu.dar.ri.sit*
			× × ×‿×		× ×‿× ×		× ×‿× × ×
		GF$_H$	× ×⟪×‿×	GF$_H$	×⟪×‿× ×	GF$_H$	×⟪×‿× × ×
		GF$_\#$	⟪× ×⟪×‿×	GB	×⟪×‿×⟩×	GB	×⟪×‿×⟩× ×
		GB	⟪× ×⟩⟪×‿×⟩		×⟪×‿×⟩×		×⟪×‿×⟩× ×
			sa.ka.kíːn		*mu.dár.ris*	GB	×⟪×‿×⟩× ×⟩
							mu.dar.rí.sit

The *Uny constraint on the rules plays a key role in these derivations. As always, it prevents the iterative rule from creating unary feet. Here, it also constrains GF$_\#$ and prevents it from applying in (8b,c).

Using the derivations in (8) as a models, the derivations of the remaining examples should be clear. They produce:

(9)	a.	*ʔá.ba.dan*	⟪× ×⟩×	e.	*bú.xa.la*	⟪× ×⟩×
	b.	*ni.síː*	×⟪×‿×⟩	f.	*mar.tá.ba*	⟪×‿×⟩× ×⟩
	c.	*ša.fúː*	×⟪×‿×⟩	g.	*yik.tí.bu*	⟪×‿×⟩× ×⟩
	d.	*ka.tábt*	×⟪×‿×⟩			

Other than for closing off ×‿× feet, none of the examples to this point have required multiple applications of GB.

There are words from Classical Arabic which are not part of the colloquial dialect, but which are understood by educated speakers and are easily produced by such speakers, although not used in regular speech. They are of interest because they do have long words that require multiple iterations of the iterative rule. McCarthy argues convincingly that when modern Cairene Arabic speaker pronounce these words from Classical Arabic, they are subject to the colloquial stress rules, not the Classical ones, with one exception, discussed below. He first gives a set of these words similar to the examples above and shows that the rules (7) (or his equivalent) predict the correct modern pronunciation.

(10)	a.	*da.rábt*	×⟪×́‿×⟩	‘I/you (sg.) beat’	(3a)
	b.	*haǰ.ǰáːt*	⟪×‿×⟪×́‿×⟩	‘pilgrimages’	(3a)
	c.	*ká.ta.ba*	⟪×́ ×⟩×	‘he wrote’	(3b)
	d.	*ʔin.ká.sa.ra*	⟪×‿×⟩×́ ×⟩×	‘it got broken’	(3b)
	e.	*qat.tá.la*	⟪×‿×⟩⟨×́ ×⟩	‘he killed’	(3c)
	f.	*ka.táb.ta*	×⟪×́‿×⟩×	‘you (m. sg.) wrote’	(3c)
	g.	*haː.ðáː.ni*	×⟪×́‿×⟩×	‘these (m. du.)’	(3c)
	h.	*fa.ʔa.lá.tun*	⟪×‿×⟩×́ ×⟩	‘deed (nom.)’	(3c)

We now look at longer Classical Arabic words. There is one small difference between how these words are stressed compared with what the colloquial extrametricality predicts; final CVV is metrically bimoraic in colloquial Cairene Arabic, (6c,d), but metrically monomoraic in the pronunciation of Classical words by modern Cairene Arabic speakers, (11c,e). McCarthy has an in-depth discussion of this, but for the sake of expedience, I will simply assume that the extrametricality rule extends final consonant extrametricality to all final coda beats in Classical words.

(11)	a.	*ša.ja.rá.tun*	《× ×〉×́ ×〉	'tree (nom.)'	4a
	b.	*ša.ǰa.rá.tu.hu*	《× ×〉×́ ×〉×	'his tree (nom.)'	4b
	c.	*ša.ja.ra.tu.hú.maː*	《× ×〉× ×〉×́ ×〉	'their (du.) tree (nom.)'	4a
	d.	*ʔad.wi.ya.tú.hu*	《×‿×〉× ×〉×́ ×〉	'his drugs (nom.)'	4a
	e.	*ʔad.wi.ya.tú.hu.maː*	《×‿×〉× ×〉×́ ×〉×	'their (du.) drugs (nom)'	4b

The examples (11) have much more robust iterative rule application than the earlier examples. They support the rule system (7).

Section 3. Variations of the Cairene Arabic stress system

In the coming pages I want to fill in the detail of Figure 1 (possibly at the top of the next page) to show how various dialects of Arabic relate to Cairene Arabic. No claim is made that Cairene Arabic takes diachronic precedence; but it does serve as a convenient way to compare the stress systems. The changes are highlighted with a dotted box. $GF_{\#}$, GF_{H}, and GB have exactly the same meaning that they have in the Cairene rules (7).

The next three sections will show how these variations affect the stress patterns generated. Showing how the Cyrenician Bedouin footing system (the same as Negev Bedouin system) produces the observed surface forms is by far the longest section since most of the surface forms are heavily affected by vowel deletion and subsequent resyllabification.

Section 4. Palestinian Arabic (PA)

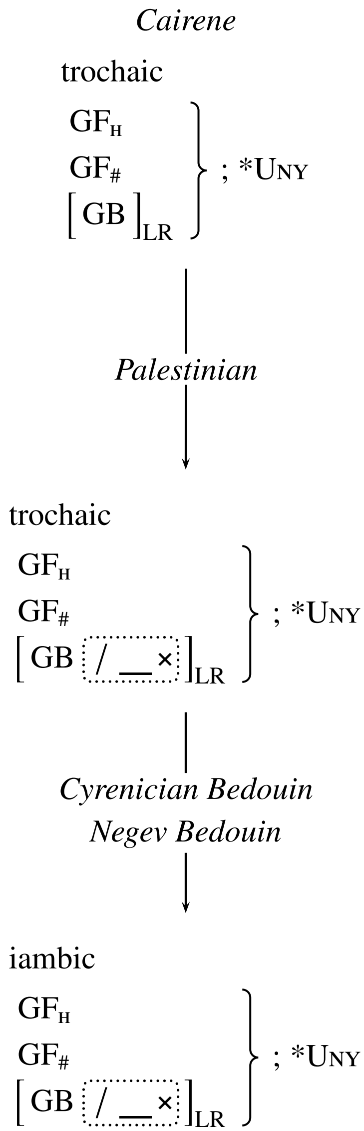
The Palestinian Arabic system (12) is just like the Cairene Arabic system, except that GB is restricted structurally to apply away from the right edge, Stress is trochaic, as it is in Cairene Arabic.

(12)
$$\left.\begin{array}{l} \times \rightarrow \langle \times \;/\; \_\_ \smile \times \\ \times \rightarrow \langle \times \;/\; \# \_\_ \\ \big[\times \rightarrow \times \rangle \;/\; \_\_ \times \big]_{LR} \end{array}\right\} ;\ {}^{*}\mathrm{U}_{\mathrm{NY}} \quad \begin{array}{l} (GF_{H}) \\ (GF_{\#}) \\ (GB) \end{array}$$

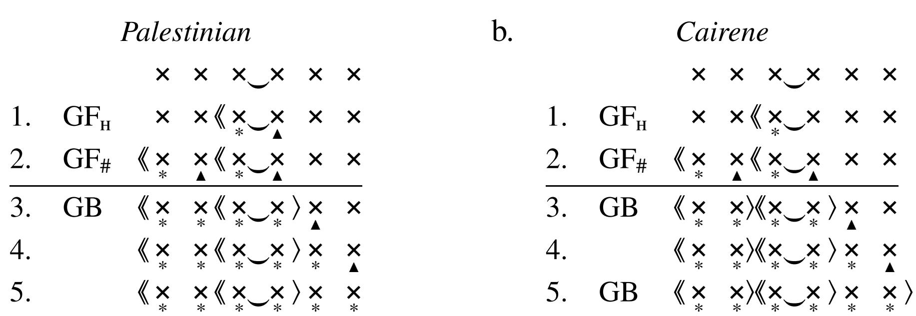
Contrast the derivation (13a) in the Palestinian system with (13b), which is what the Cairene rules applied to the same form would produce. Once the iterative rule operates (below the horizontal separator), the current targets of the iterative rule are marked with a cursor.

Figure 1

All the dialects are mora-counting, have main stress right and suppress secondary stress, so that a single stressed syllable appears at the surface.



(13) a. b.



If the reader understands the course of the derivations (13), the derivations which produce the forms in (14) are easy to work out. In addition to showing the delimiter insertion resulting from applying the Palestinian Arabic rules, which are responsible for the stress in the examples, another column shows what would be produced by the Cairene Arabic rules. This is useful in understanding how a small change (the structural condition on GB in Palestinian) affects the outcome. Group A are words for which both systems produce the same outcome, although steps in the derivations will differ. Group B are words for which the feet produced are the same, but differently delimited. Group C is the most interesting; different feet result.

(14)		*PA rules*	*CA rules*		
A. Same delimiter pattern					
a.	*mak.ta.bít.na*	《×‿×〉×《×‿×〉×	《×‿×〉×《×‿×〉×	‘our library’	K+AK, 73
b.	*ša.ǰa.ra.tu.hu*	《× ×〉× ×〉×	《× ×〉× ×〉×	‘his tree’	K 1981, 15
c.	*ʔal.lá.ma.to*	《×‿×〉× ×〉×	《×‿×〉× ×〉×	‘she taught him’	K 1981, 15
d.	*ká.ta.bu*	《×́ ×〉×	《×́ ×〉×	‘they wrote’	K 1983, 210
B. Different delimiter pattern, but same feet					
e.	*ká.tab*	《× ×	《× ×〉	‘he wrote’	K+AK, 55
f.	*duk.kaːn*	《×‿×《×‿×	《×‿×〉《×‿×〉	‘shop’	K 1983,212
g.	*moː.la.déːn*	《×‿×〉×《×‿×	《×‿×〉×《×‿×〉	‘two feasts’	K 1983, 208
C. Different feet and different stress					
h.	*bá.ka.ri.to*	《×́ ×〉× ×	《× ×〉×́ ×〉	‘his cow’	K+AK, 73
i.	*ʔál.la.mat*	《×́‿×〉× ×	《×‿×〉×́ ×〉	‘she taught’	K+AK, 73

The examples are all taken from Hayes (1995) because the original sources were not available to me. At the right above, are Hayes’ source references: Kenstowicz and Abdul-Karim (1980), Kenstowicz (1981), and Kenstowicz (1983).

Section 5. Negev Bedouin Arabic (NBA)

First, some data. The source is Blanc (1970). The first discussion in a metrical framework was Kenstowicz (1981, 1983).

(15)					
	a.	*bi.ná*	《× ×́	he built	B 124
	b.	*a.ʔá.ma*	《× ×́〉×	blind	B 124
	c.	*za.lá.ma.tak*	《× ×́〉× ×	your man	B 121
	d.	*ga.ha.wa.tíːh*	《× ×〉×《×‿×	my coffee	B 142
	e.	*ɣa.nám.na*	×《×‿×́〉×	our sheep	B 120
	f.	*as.táf.ha.mah*	《×‿×《×‿×́〉× ×	he queried him	B 132
	g.	*an.ki.tá.law*	《×‿×〉× ×́〉×	they were killed	B 121

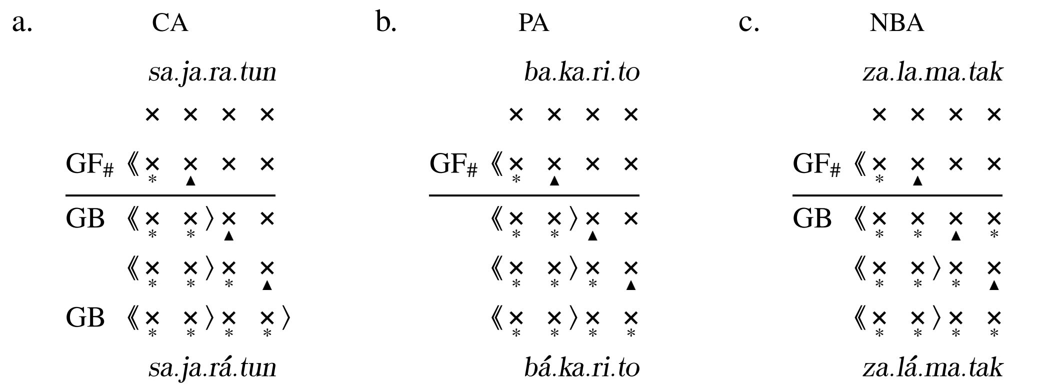
The NBA delimiter insertion rules are exactly the same as the Palestinian ones. They are repeated below in (16). We will see later that the delimiter insertion rules are also the same in Cyrenician Bedouin Arabic.

(16)
$$\left.\begin{array}{l} \times \rightarrow \langle \times \;/\; \_\_ \smile \times \\ \times \rightarrow \langle \times \;/\; \#\_\_ \\ \left[\times \rightarrow \rangle \times\right]_{LR} \end{array}\right\} ;\ {*}\mathrm{U_{NY}} \qquad \begin{array}{l}(GF_{H})\\(GF_{\#})\\(GB)\end{array}$$

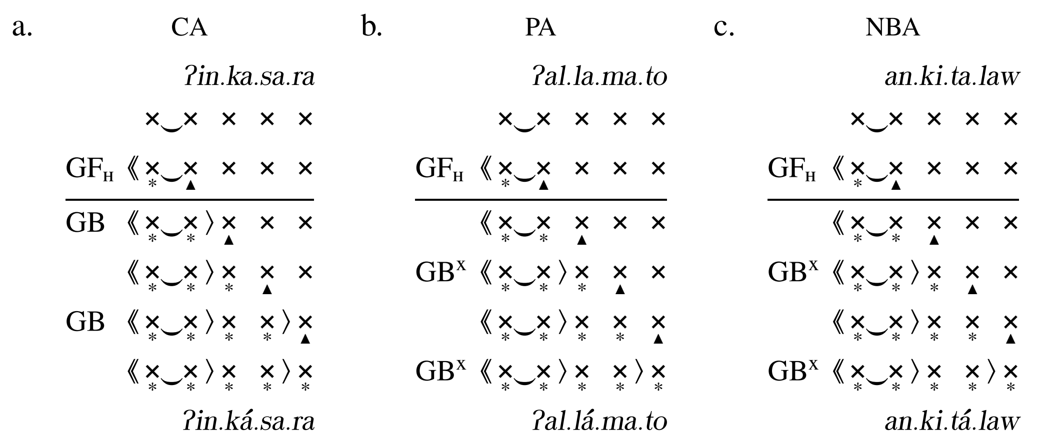
Crucially, however, CA stress is on the leftmost beat of the rightmost foot while in NBA it is on the rightmost beat of the rightmost foot.

Below is a comparison of CA, PA, and NBA.

(17)

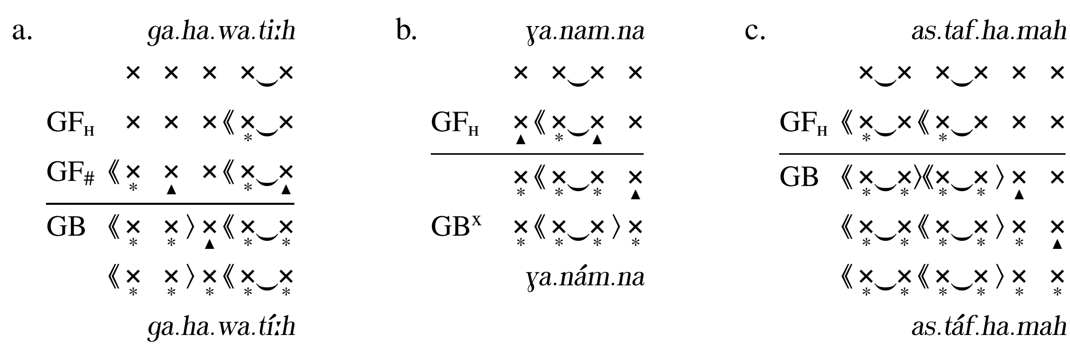


(18)



Here are some NBA examples in which there is heavy syllable away from the edge.

(19)



Section 6. Cyrenician Bedouin Arabic (CBA)

What makes CBA particularly interesting is the conjunction of two things. First, there is extensive vowel deletion. Second, metric structure that is established before vowel deletion persists into late stages in the derivation, often in a highly distorted form. Vowel deletion in CBA sometimes leaves sequences of up to 3 unsyllabified consonants, necessitating extensive resyllabification, which must preserve the foot structure as it rebuilds the syllable structure. I will begin by looking at some examples with no vowel deletion and show that the Negev Bedouin system makes the correct prediction. Then show how syllabification is carried out. This is needed to understand the interaction of vowel deletion and metrical structure since resyllabification is carried out by the same rules that carry out syllabification. We can then analyze the way metrical structure survives vowel deletion and resyllabification.

Here are some examples with no vowel deletion.

(20)	underlying	surface	footing		
a.	*maʔ.ra.kɨt.ha*	*maʔ.rɨ.kɨ́t.ha*	*⟪maʔ⟩ra⟪kɨt⟩ha*	‘her quarrel’	M 91
b.	*ka.tab*	*ka.táb*	*⟪ka.tab*	‘he wrote’	M 84
c.	*mak.tab*	*mák.tab*	*⟪mak⟩tab*	‘office’	M 84
d.	*ka.tab.tan*	*ki.táb.tan*	*ka⟪tab⟩tan*	‘you (f. pl.) wrote’	M 89
e.	*ta.raː.fa.gan*	*tɨ.ráː.fɨ.gan*	*ta⟪raː⟩fa.gan*	‘they (f.) accompanied’	M 91
f.	*fa.naː.ǰiːl*	*fa.naː.ǰíːl*	*fa⟪naː⟪ǰiːl*	‘cups’	M 90

In (20d, e), a segmental rule has raised *a/ɑ* to *i*. Note that there are 2 unfooted beats at the right edge (20e). This is characteristic of Palestinian footing.

6.1 Syllables and moras

I assume that syllables in CBA are built out of moras. This is a more substantial assumption than it might seem. If syllables are indeed built out of moras, it means that moras have to be built first. That is, there is a process of morafication which precedes syllabification.

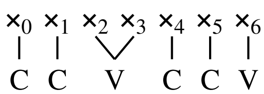
6.1.1. Morafication

In Frampton (2011) I argue that syllabification proceeds outwards from local sonority maxima by iterating a traditional rule scheme (which is, or course, language particular). Morafication and syllabification in CBA can be analyzed in the same way. Crucially, the order in which the iterative rules target the timing slots depends only secondarily on direction. It depends primarily on relative sonority. We first consider the precedence $\mathcal{M}$, which determines the locus of morafication and syllabification in CBA (and many other languages).

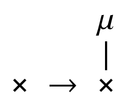
(21) $\mathcal{M} = \begin{bmatrix} \text{Sonority} \\ \text{Left} \end{bmatrix}$

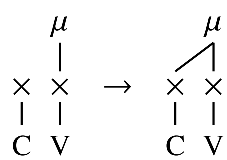
$\mathcal{M}$ is a relation between timing slots, where the relative sonority of a timing slots is taken to be the relative sonority of the phonemes they are associated with. Relative sonority of phonemes is very simple in CBA, with only two levels. Vowels are more sonorous than consonants.

We are interested establishing which timing slots in the set of unmorafied timing slots are targeted by the morafication rules at each stage of the morafication process. The local maxima of $\mathcal{M}$ on a subset U of the timing slots are the $\times$ in U such that $\times >_{\mathcal{M}} \times'$ for any $\times'$ in U which is adjacent to $\times$. $\times$ has greater sonority than its neighbors, or has greater sonority than its neighbor on the right (if it has one) and is at least as sonorous as it neighbor on the right. If U is non-empty, there will be at least one local maximum, and there will never be adjacent local maxima because if they have the same sonority, one will be to the left of the other. In (22), for example, $\times_0$, $\times_2$, and $\times_6$ are the local maxima.

(22) 

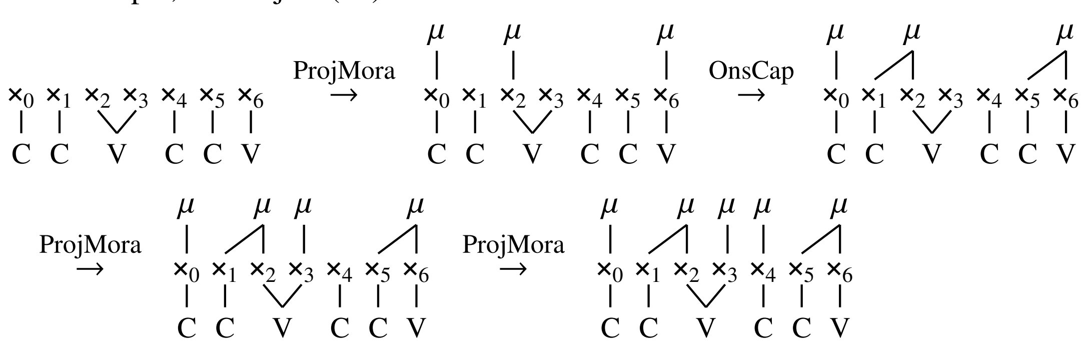
The morafication rules are simple.

(23) Mora Projection (ProjMora):  ATB application

Onset Capture (OnsCap):  persistent application

At each iterative step, ProjMora applies across-the-board to all the local $\mathcal{M}$-maxima in the set of unmorafied timing slots. OnsCap, a persistent rule, applies automatically whenever its conditions are met; this can (and will) be between iterations of the morafication rule or iterations of the syllabification scheme (see below).

As an example, we subject (22) to the morafication rules.

(24) 

6.1.2. Syllabification

$\mathcal{M}$ is a relation between timing slots. It lifts to a relation between moras if we take the sonority of a mora to be the sonority of the most sonorous slot in the mora. After morafication, a scheme of elementary syllabification rules applies iteratively to the local maxima of $\mathcal{M}$ among the unsyllabified moras. The subrules are subject to CBA syllable well-formedness: syllables must be of the form $[\mu_1(\mu_2)]_\sigma$, with μ_1 of the form $[(\mathrm{C})\mathrm{V}]_\mu$ and μ_2 of the form $[\mathrm{X}]_\mu$. The parenthesis indicate optionality, not constituent boundary. Four elementary rules are used, given in (25). Following Ito (1986), the epenthesis rules are taken to be syllabification rules.

It has been known since Selkirk (1981) that there are dialectical differences between Arabic languages in how stray consonants are integrated into the syllable structure. She observed that some dialects use $C \rightarrow C\text{ə}$, others use $C \rightarrow \text{ə}C$. The schwa symbol ə is used here as an abstract symbol for ‘epenthesized vowel’, not as schwa phoneme. It makes it much easier to follow the derivations if an abstract symbol is used. The quality of the epenthetic vowel plays no role in what follows. As Hayes discovered, CBA uses both kinds of epenthesis. If there is a sequence of stray consonants, then CBA epenthesizes a vowel to the right of the leftmost one. If there is an isolated nonfinal stray consonant, the vowel is epenthesized to its left.

(25) Syllabification Operations (all constrained by syllable well-formedness)

a. Adjoin Coda (AdjCoda): $\begin{array}{c}\sigma\\ \mid\\ \mu\end{array} \rightarrow \begin{array}{c}\sigma\\ \mid\diagdown\\ \mu'\ \mu\end{array} \;/\; \begin{array}{c}\sigma\\ \mid\\ \mu'\end{array}$ __

b. Project Syllable (ProjSyl): $\mu \rightarrow \begin{array}{c}\sigma\\ \mid\\ \mu\end{array}$

c. CV Epenthesis (CVep): $\begin{array}{c}\mu\\ \mid\\ \times\\ \mid\\ \mathrm{C}\end{array} \rightarrow \begin{array}{c}\sigma\\ \mid\\ \mu\\ \mid\diagdown\\ \times\ \times\\ \mid\ \ \mid\\ \mathrm{C}\ \text{ə}\end{array}$ / __ μ', μ' unsyllabifiedd

d. VC Epenthesis (VCep): $\begin{array}{c}\mu\\ \mid\\ \times\\ \mid\\ \mathrm{C}\end{array} \rightarrow \begin{array}{c}\sigma\\ \mid\diagdown\\ \mu\ \mu\\ \mid\ \ \mid\\ \times\ \times\\ \mid\ \ \mid\\ \text{ə}\ \mathrm{C}\end{array}$ / __ μ', μ' syllabified

The syllabification scheme, using the operations (25), is given in (26). Note that the epenthesis operations have contextual restrictions. VCep applies only to a mora which is immediately to the left of an already syllabified mora. CVep applies only to nonfinal moras. It follows that neither rule applies to a terminal mora, which can be syllabified only by adjoining as a coda or by projecting a syllable.

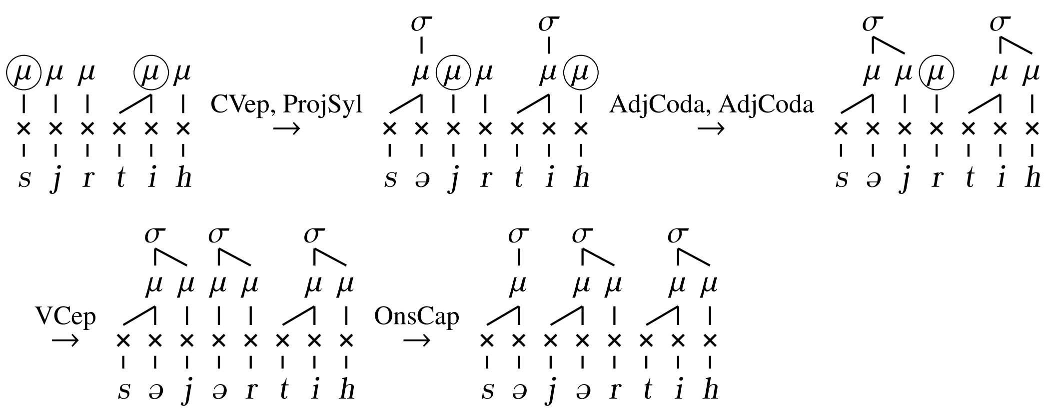
(26) Syllabification scheme: $\mathcal{S} = \begin{bmatrix} \text{AdjCoda} \\ \text{ProjSyl} \\ \text{CVep} \\ \text{VCep} \end{bmatrix}$

There is a natural order, with subrules which require less new structure ordered before those that require more. AdjCoda requires no structure, just reassociation. ProjSyl builds a new syllable. VCep is the only rule that epenthesizes a mora in addition to a vowel. Although they do have a natural order, the order of the last two rules plays no role because the two rules cannot both be applicable to the same mora.

I assume that S applies iteratively ATB to the current set of local $\mathcal{M}$-maxima. But iterative appliation of S to an arbitrarily chosen local $\mathcal{M}$-maximum yields the same result. So the leftmost $\mathcal{M}$-maxima can be targetted at each step, or the rightmost $\mathcal{M}$-maxima, with the same result.

The following derivation illustrates all of the syllabification rules. The local $\mathcal{M}$-maxima among the unsyllabified moras are indicated at each stage by circling the mora.

(27)



Section 7. The effect of vowel deletion on metrical structure

This section leans heavily on Hayes (1995, pp. 228–39), who relied on Mitchell (1960, 1975) for the data and Langendoen (1968) for an early formulation of the segmental rules. All of the examples are directly from Hayes; I was not able to consult his sources. References ‘M *x*’ are to page *x* in Mitchell’s 1975 work. The details of the segmental phonology and an understanding of the general contours of the metrical phenomenon at issue are from Hayes; I could not have proceeded without that. But the analysis below diverges sharply on the question of how metrical structure survives processes which alter syllable structure. The device of ‘floating stress’ is eliminated completely.

7.1 Vowel deletion

There are 3 major segmental rules which are needed in order to understand how underlying metrical structures appear at the surface. One or the other of them applies to the vowel of every nonfinal CV syllable, which never appears unmodified at the surface.

(28) Suppose v is the vowel of a nonfinal CV syllable σ.

Low Vowel Deletion (LVD):
If σ is followed by a nonfinal CV syllable, then v deletes.

High Vowel Deletion (HVD): If v is +HIGH, then v deletes.

Low Vowel Raising (LVR): If v is low, then v raises to +HIGH.

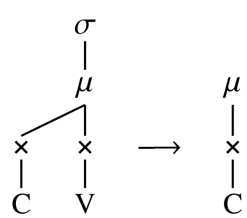
I have called the first rule Low Vowel Deletion even though the structural description does not specify that the target is low. It could equally been specified as −HIGH because +HIGH vowels will be deleted in any event by High Vowel Deletion. Phenomenologically, it is low vowel deletion.

There are clearly ordering issues because the rules interact. In *ʃa.ǰa.ri.tih* for example, if LVD applies to the second low vowel, the environment for applying LVD to the first vowel is destroyed. As we will see, both low vowels must delete. Consequently, LVD must apply from left to right or ATB. In the same example, if HVD applied before LVD, the vowel of the *ri* syllable would delete, destroying the environment for LVD application to the vowel of the *ǰa* syllable. If LVR applied before HVD, then low vowels would always delete, but they do not. I will assume that the scheme

$$\begin{bmatrix} \text{LVD} \\ \text{HVD} \\ \text{LVR} \end{bmatrix}$$

applies ATB. LR application would have the same effect, but there is no need to specify a directional iterative rule.

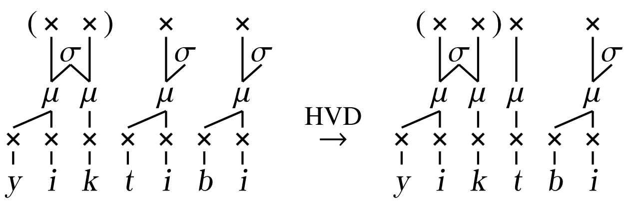
What happens to the moraic and syllable structure when the vowel is deleted? The syllable mark must be deleted as well, because the result is not a well-formed syllable. But the mora is perfectly well formed. So deletion accomplishes:

(29) 

The consonantal moras which vowel deletion leaves are crucial in understanding how vowel deletion and subsequent resyllabification affect the metrical structure. The remnant consonantal moras provide a framework for rebuilding the syllable structure. Remember that consonantal moras were important in the syllabification process, so it should be no surprise that they play a role in resyllabification.

CBA is mora counting, so moras (except for word-final consonantal moras) project metrical beats. Since moras survive vowel deletion, these metrical beats survive as well. So for example:

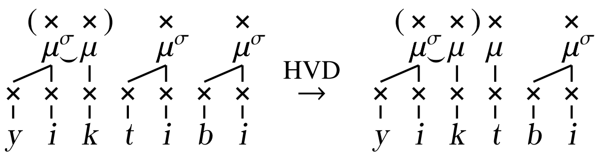
(30)



The second syllable does not survive, but its mora does.

The notation is cumbersome, so the following more compact notation will be used.

(31)



The data which must be accounted for is (32). The second column is what is produced by the (30) rules. The vowel deletions are obvious; the *i* that results from LVR is annotated (for the reader, not the grammar) as $\underset{\wedge}{i}$. The task will be to show how the data is a consequence of the metrical structure of the underlying form and resyllabification.

(32)

	underlying		observed		
A. Single initial consonantal mora					
a.	*gi.til*	*g$\bcancel{i}$.til*	*ig.tíl*	'he was killed'	M 85
b.	*li.fa.fih*	*l$\bcancel{i}$.f$\underset{\wedge}{i}$.fih*	*il.fí.fih*	'bundle'	M 91
c.	*ša.ǰa.rit.ha*	*š$\bcancel{a}$.ǰ$\underset{\wedge}{i}$.rit.ha*	*iš.ǰi.rít.ta*	'her tree'	M 90
d.	*ka.ta.baː.tih*	*k$\bcancel{a}$.t$\underset{\wedge}{i}$.baː.tih*	*ik.ti.bíɛ.tih*	'she wrote it'	M 84
B. Single consonantal mora following a closed syllable					
e.	*yik.ti.bi*	*yik.t$\bcancel{i}$.bi*	*yí.kit.bu*	'they (m.) write'	M 84
f.	*in.ga.ta.lat*	*in.g$\bcancel{a}$.t$\underset{\wedge}{i}$.lat*	*i.nig.tí.lat*	'she was killed'	M 87
C. Sequence of two consonantal moras					
g.	*ki.ti.bih*	*k$\bcancel{i}$.t$\bcancel{i}$.bih*	*kít.bih*	'his books'	M 88
h.	*faː.ki.hi.tih*	*faː.k$\bcancel{i}$.h$\bcancel{i}$.tih*	*faː.kíh.tih*	'his fruit'	M 88
i.	*yin.ga.ti.li*	*yin.g$\bcancel{a}$.t$\bcancel{i}$.li*	*yin.gít.lu*	'they (m.) can or will be killed'	M 89
D. Sequence of 3 consonantal moras					
j.	*ša.ǰa.ri.tih*	*š$\bcancel{a}$.ǰ$\bcancel{a}$.r$\bcancel{i}$.tih*	*ší.ǰɨr.tih*	'his tree'	M n. 40

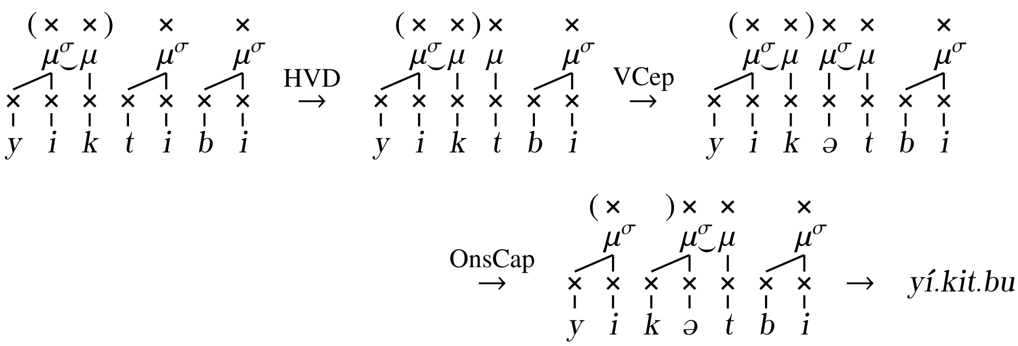
The data has syllable structure changes throughout. Half of the examples have main stress which is not what is expected on the basis of the surface form. Most surprising are (32e,j), which have stress on an initial light syllable.

(33) Unexpected stress shift

expected		observed	
(íg)til	–́ ◡	*ig.tíl*	– ◡́
(íl)fi.fih	–́ ◡ ◡	*il.fí.fih*	– ◡́ ◡
yi(kít)bu	◡ –́ ◡	*yí.kit.bu*	◡́ – ◡
i(níg)ti.lat	◡ –́ ◡ ◡	*i.nig.tí.lat*	◡ – ◡́ ◡
si(jír)tih	◡ –́ ◡	*sí.jir.tih*	◡́ – ◡

Four full derivations follow, one from each of the 4 groups in (32). We start with (32e) from Group B. The first step in the derivation was given in (31), but will be repeated here.

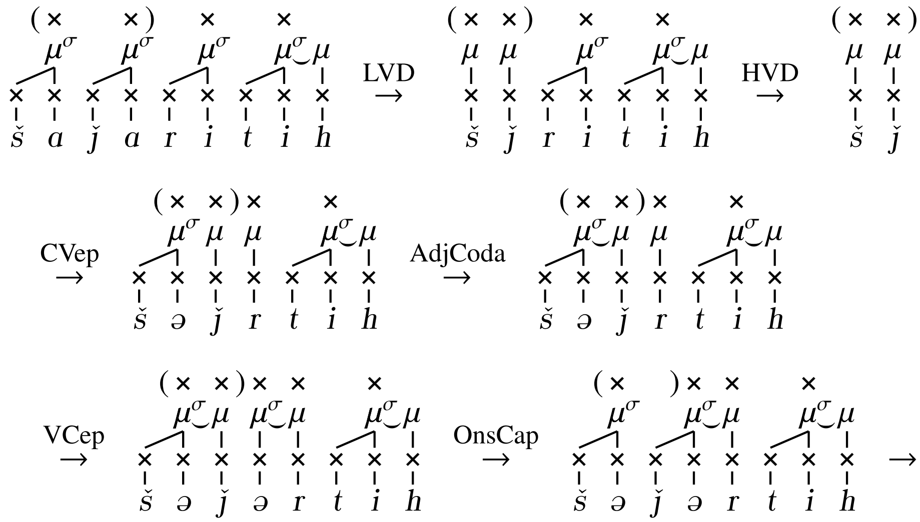
(34) – ◡ ◡ → ◡́ – ◡



Note what has happened here. In order to syllabify the unsyllabified consonantal mora $[t]_\mu$, epenthesis creates a mora outside the foot. But then onset capture results in the loss of a mora inside the foot. Superficially, it looks like a mora has moved, but that is not what actually happened. The outcome is *yí.kət.bi*. There is a minor segmental rule which realizes final *i* as *u* and the epenthetic vowl as *i*. This gives (32e), *yí.kit.bu*, as desired. The other examples in (32B) are similar.

The derivation of (32j) from group D uses almost all of the rules discussed earlier.

(35) ◡ ◡ ◡ ◡ → ◡́ – ◡

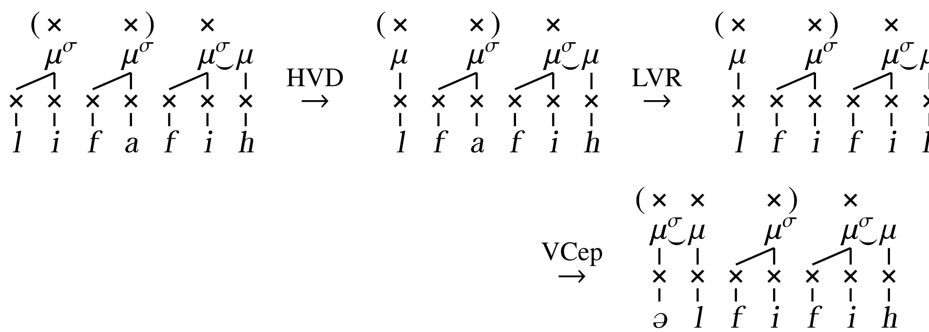


→ *ší.ǰir.tih*

It is important here that HVD applies after LVD, otherwise *ša.ǰa.ri.tih* → *ša.ǰa.r~~i~~.tih* would eliminate the context for LVD to delete the second low vowel. It is also important that LVD apply either ATB or left to right, otherwise *ša.ǰa.ri.tih* → *ša.ǰ~~a~~.ri.tih* would eliminate the context for deleting the first low vowel.

(36) derives (32b), from the A Group.

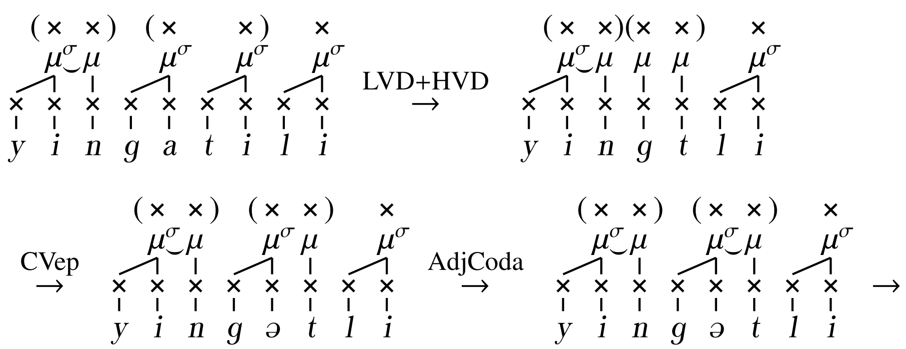
(36) ◡ ◡ ◡ → – ◡́ ◡



→ *il.fí.fih*

(37) derives (32i) from the C group.

(37) – ◡ ◡ ◡ → – –́ ◡



→ *yin.gít.lu*

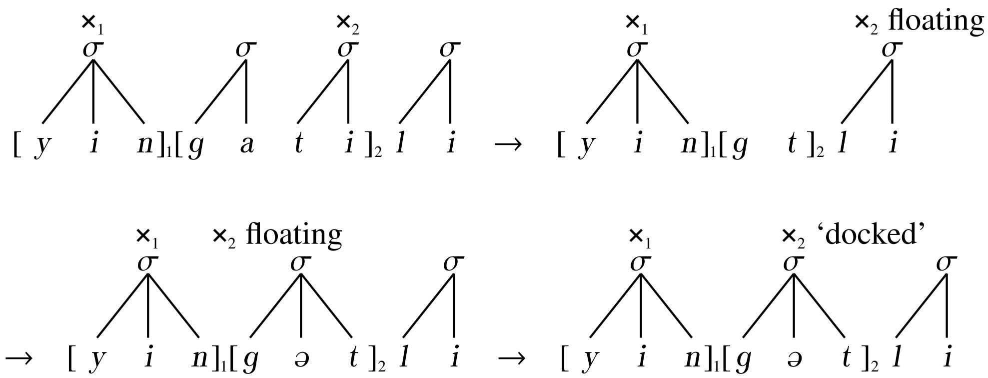
Note that both vowels have been deleted in the second foot, which is reduced to a pair of unsyllabified consonantal moras.

7.2 Hayes' analysis

Since I use Hayes' (1995) analysis so heavily, I need to justify that a reanalysis is called for. It is clearly desirable to remove an appeal to 'floating' stress. But there are other issues as well. The core question is the relationship between footing and stress assignment. Hayes assumes that there is no such thing as a stressless foot.[7] It follows from this that vowel deletion must be able to cause movement of stress from one stressed element to another. CBA vowel deletion taxes this understanding because all the vowels in a foot can be deleted. What then happens to the foot and its stress? Stress cannot simply move from one stressed element in the foot to another.

Hayes' offers the following solution. He defines a foot as a pair; a span of timing slots and a beat on the line of stress beats which is coindexed with the span. Several well-formedness conditions must be satisfied. First, no syllable is only partially contained in the span. Second, the stress beat associates with a syllable in the span, if there is one. The derivation *(yin)(ga.tí)li* → *(yin)(gə́t)li* in these terms is given below.

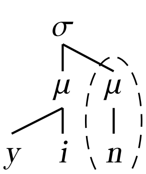
7. It can be that the stress is not realized at the surface, but that is a different question.

(38) 

Associating with a syllable is what is colorfully called 'docking'. It is represented in these diagrams by placing the beat directly above the syllable, with association implicit in this positioning.

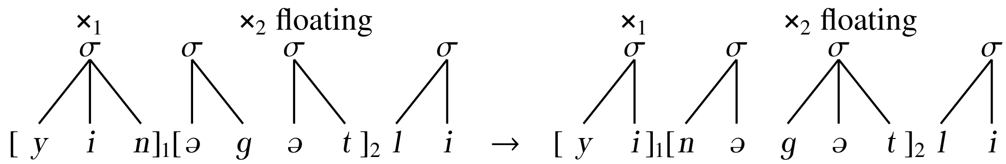
The apparatus which is called on is extensive. Feet now become a multi-tiered construction: as an object, they are a span of timing slots coindexed with a stress object on a stress tier. But in order to form them, syllables are grouped into groups of total size 2, with the size of individual syllables measured by counting done on the mora tier. The notion of autosegmental stress is needed. This autosegmental stress object is, on the one hand, associated with a syllable (at least initially and finally) and, on the other, coindexed with a span of timing slots.

Hayes is forced into this intricate analysis because it must be the case that the *gt* consonant sequence survives vowel deletion as a foot, but there is no recognition that moras can survive vowel deletion. See his (218d, p. 235), in which mora deletion accompanies vowel deletion. Why is it assumed that vowel deletion must delete moras? It is peculiar, because it is recognized that there are consonantal moras. Heavy syllable are represented as (39) by Hayes, so consonantal moras are admitted into the theory if (39) is to be taken seriously.

(39) 

The only justification for assuming that μ deletion must accompany σ deletion is the assumption that moras exist only as constituents of syllables. This amounts to accepting McCawley's clever quip that a mora is "something of which a long syllable consists of two and a short syllable consists of one." This rejects the idea that syllables are built out of moras.

There is another argument against Hayes' analysis. In (39) there was only one syllable. But if the epenthesis rules were different (only VCep, no CVep), the derivation would be (40). Where does the floating stress beat dock?

(40) 

If there were some system parameter ‘iambic’, it could be appealed to in order to determine that docking is rightmost. But if a system parameter can be used to determine the docking is rightmost in the span, then floating stress has played no role in final stress. It could simply be assigned at that point; no history is involved. Stress could be assigned persistently, whenever there was a syllable to support it.

What then is the appeal of the idea of floating stress? As far as I can tell, it traces to the roots of the modern theory of metrical phonology in analogy to syntax. Stress was thought of as the head of a foot, analogous to the verb as the head of a verb phrase. Just as there could be no phrase without a head, as was thought at the time, there could be no foot without a stress. So there could be no stage in the derivation in which there was no stress projected from a foot. But we should by this point be long past this analogy phase, as productive as it once was. The question now is what gives the most satisfactory analysis.

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