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96. Metrical patterns

1. Introduction

Metrical patterns in languages are obtained by combining various elements of prosodic structure: syllables and their constituents, feet, and other higher level organisational units like prosodic words, phrases and so on. Within a given metrical organisation, a particular constituent may be the most prominent. This relative prominence is marked by stress, which is the central theme of this article. Stress, under this conception, is not merely a phonetic feature, but is the means of marking relative prominence within various organisational groupings of metrical units (cf. Liberman 1975; see the articles by Kager, and Halle & Idsardi in Goldsmith 1995 for surveys of different metrical theories of stress). In order to establish stress patterns, we first discuss how different metrical constituents are relevant for the phonological systems as a whole. Since the covariation of linguistic variables is fundamental to language typology (cf. Plank 1997), our goal is not merely to list the observed metrical patterns, but also to examine possible relationships between the different patterns.

To this end we will focus on 'metrical coherence' from two perspectives and address the following questions. First, we ask whether a given metrical constituent varies in its properties within a single language. For instance, the metrical constituent 'foot' is generally used to account for word stress. However, there may be other processes which are sensitive to foot structure. If so, one would like to know if foot types vary for different processes within a given language, or whether with respect to a given metrical constituent, the system is coherent (Dresher & Lahiri 1991). The second issue is whether the type of stress a language has can predict the properties of its metrical constituents. This particular perspective has not been an issue in the phonological descriptions of metrical patterns, but is extensively discussed in typological literature on the covariation of stress with the nature of syllables, headedness of phrasal stress and such (cf. Donegan & Stampe 1983; Gil 1986). Thus, we begin by motivating syllables and feet as necessary metrical constituents in the description of phonological systems. For each of the constituents we provide evidence from segmental processes as well as for stress, and then move on to issues on metrical coherence and covariation of metrical units, which are rather crucial for typological research.

2. The Syllable as a constituent

In this section, we first review the syllable's status in phonology before discussing the role of the syllable in the assignment of stress. The syllable has traditionally been assumed to consist of an onset followed by a rhyme which is divided into a nucleus and a coda. The nucleus is the obligatory and most important part of the syllable, while the onset and coda are optional. The most frequent syllable inventory in natural language consists of the following: V, CV, VC, CVC (see Blevins 1995 for a survey). The more complex syllable inventories arise from including more segmental material in the onset and the coda, and even the nucleus can be branching. Complex onsets and codas are generally governed by the *Sonority Scale* which states that onset consonants increase in sonority and codas decrease in their sonority (cf. Clements & Hume 1995). The accepted sonority scale in terms of rising sonority is obstruents < nasals < liquids < glides < vowels.

The notions 'closed' and 'open' syllables play an important role in phonology. Closed syllables are those which are closed by a coda consonant, while open syllables end in a vowel (long or short) or a diphthong. To decide whether medial consonants are part of onsets or codas, the principle of maximisation of the onset is often invoked. That is, when there is more than one intervocalic consonant, whether all of them are part of the onset of the second syllable, depends on whether the language permits 'maximising the onset' based on sonority principles. Phonological processes can help determine whether consonants fall in the coda or not. This is illustrated with an example from German which has a process of syllable final devoicing. The data are from Vennemann (1972). German has a rule of syncopation which follows for the following types of alternations.

(1) Syncope and syllable final devoicing in German

Standard German

	'flirt'	'sail'	'go by bicycle'
Infinitive	li:bəl+n	ze:gəl+n	ra:dəl+n
1SG.IND.PRES	li:bl+ə	ze:gl+ə	ra:dl+ə
Standard German, Northern pronunciation			
	li:bl+ə	ze:gl+ə	ra:**tl**+ə

After syncopation, the consonant clusters that are created are not equally accepted as onsets in the Standard German as compared to the Northern pronunciation. In Standard German, the sequence [dl] is accepted as a syllable onset, and the maximisation of onset prevents the [d] being in the coda. Hence, coda-devoicing does not apply. In contrast, the Northern pronunciation which allows [bl] and [gl] clusters, permits maximisation of consonants in these cases, but prevents [dl] from being part of an onset. As a result, coda-devoicing applies and the surface form is [ra:t.lə] rather than *[ra:.dlə].

Maximisation of the onset is closely related to the notion of a core syllable, or a CV syllable. There is a general tendency to avoid onsetless syllables such that in most if not all languages, a VCV string is syllabified as [V.CV]. Resyllabification to prevent onsetless syllables is central to the analysis of German devoicing as well (cf. Rubach 1990, Giegerich 1992). The following alternations are relevant.

(2) Resyllabification in German

glau**b**	[p]	glau**b**-en	[b]	glau**b**-lich	[p/b]	'believe' 2SG IMP./INF./ADJ.
Ta**g**	[k]	Ta**g**-e	[g]	tä**g**-lich	[k/g]	'day' SG./PL./ADV.

As we have seen before, coda devoicing makes the word final consonants in the first column voiceless. A suffix vowel is added to the words in the second column. Here the medial sequence VCV is syllabified as [V.CV] forcing the medial consonant to be an onset, thereby blocking coda devoicing. Oddly enough, when the suffix begins with a sonorant consonant, and although the obstruent + liquid is a possible onset (as we saw in the previous example), resyllabification can be blocked for certain speakers and coda devoicing applies. Obviously, for those speakers who devoice the obstruents, resyllabification is sensitive to certain morphemes even if allowable onsets may arise. However, the crucial point is that when a suffix with an initial vowel follows, resyllabification is obligatory since German always requires a syllable with an onset.

Words or syllables without a surface consonant are always preceded by a glottal stop: cf. *Atmen* [ʔatmən] 'breathing', *abteilen* [ʔapta͜ilən] 'to separate', *mitarbeiten* [mɪtʔarba͜itən] 'to cooperate' etc. For some speakers the glottal stop insertion is restricted to stressed syllables; hence, *Theater* [tʰeʔáːtɐ]) 'theatre', but *Bebauung* [bebá͜ʊʊŋ] 'building development', and not [bebá͜ʊʔʊŋ].

2.1. Preferred syllable structure

Once we accept the fact that languages have preferred syllable structures, any deviation from these preferences are repaired. Strategies for repairing them can differ. For instance, if affixation leads to unacceptable syllables, either epenthesis or syncope are invoked to maintain the preferred structures. In a language like Koryak (a Paleosiberian language spoken in Kamchatka; Spencer 1996: 63−64), the most complex syllable structure permitted is CVC. Hence any affixation which leads to complex structures is resolved by schwa epenthesis.

(3) Koryak schwa epenthesis
Verb root /pŋlo/ 'ask'
Prefixes: *t-* 1SG.SUBJ. *mt-* 1PL.SUBJ., *na-* 3PL.SUBJ.

(a) t-pŋlo-n	təp.ŋə.lon	'I asked him'
(b) mt-pŋlo-n	mət.pəŋ.lon	'we asked him'
(c) na-pŋlo-n	nap.ŋə.lon	'they asked him'

If the segments are syllabified from left to right obeying the preferred CVC syllabic template, then the introduction of the schwa is entirely predictable. If we did not assume that epenthesis was syllable based, it would not be possible to account for the difference between the schwa insertions in the verb root in (3a) and (3b): *pŋəl* vs. *pəŋl*.

Epenthesis is one of the most frequent ways to resolve unwanted clusters and to obtain a preferred syllable template. Related languages often exhibit a difference in the acceptance of initial and final clusters. A striking example comes from certain final liquid + obstruent clusters in Germanic languages. English and German allow [l + obstruent] clusters in words like *milk* or *Milch*, but Dutch disallows such clusters and introduces a schwa as in *melək*.

Along with epenthesis, deletion is another means for cluster simplification. In Bengali, the present indicative ending begins with a geminate affricate *-tʃtʃʰ* which is degeminated when added to a verb root ending in a consonant (Fitzpatrick-Cole 1994, 1996; Lahiri 2000).

(4) Bengali degemination as cluster simplification

(a) ʃu-lɑm	ʃu-tʃtʃʰi		'sleep 1PAST/1PRESENT'
(b) boʃ-lɑm	boʃ-tʃʰi	*boʃ-tʃtʃʰi	'sit 1PAST/1PRESENT'

Bengali does not allow coda clusters. Since a geminate consonant belongs to the coda of one syllable and the onset of the following syllable, if the preceding syllable ends in a consonant, the geminate introduces a coda cluster and is degeminated to fit the syllable template of the language.

Thus, both deletions and insertions are frequently found in languages, and almost always in the context of repairing an unacceptable syllable. Preference for syllable types, and hence repairs, is usually restricted to the lexical level. In the postlexical level, there is more variation. The last example of degemination can also be viewed as shortening, and as we will see in § 2.3., lengthening and shortening phenomena are also linked to syllable structure. However, in these cases it is the weight of the syllable which plays a crucial role.

2.2. Syllable quantity and weight

One view of representing syllable weight is by using moras. The moraic theory of representation views moras as phonological positions which come between prosody and segments (rooted in the feature tree). Long and short vowels, and long and short consonants (i. e. geminate and single consonants) are differentiated by their moraic representation. Moraic representations in (5) are based on Hayes (1989).

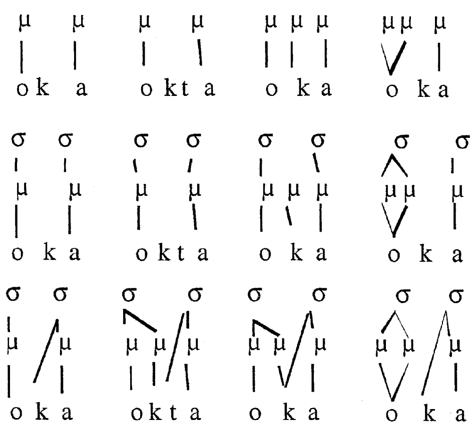
(5) Moraic representations

```
μ      μ μ            μ
|      \ /     |      |
[a]    [aː]    [p]    [pː]
```

Short vowels have one mora, long vowels have two moras, a single consonant has no moras, and a geminate consonant comes with one mora. A single consonant is not assigned a mora in the lexical representation. It may or may not be assigned a mora depending on whether it is in the coda and whether the language treats closed syllables as heavy. If the coda is counted as heavy, then weight-by-position assigns a mora to the coda consonant. Geminates, on the other hand, are part of the onset of a syllable, but must close the preceding syllable as well, automatically adding weight to this syllable. (A problem arises in languages where geminates do not contribute to weight but long vowels do; see Lahiri & Koreman (1988), Hayes (1989), Kager (1989) for further discussion.) Hypothetical syllabifications are given below.

(6) Syllable structure assignment

[oka] [okta] [okka] [o:ka]



Just as languages often try to preserve preferred syllable structures, we often find processes which attempt to maintain the weight of a syllable. Bimoraic syllables are heavy, irrespective of whether they are closed syllables (the coda consonant adding weight to the syllable), or whether they have a long vowel. However, not all languages necessarily consider closed syllables to be heavy. Languages tend to avoid trimoraic syllables although they do exist. Further consequences of syllable weight will be discussed when we consider stress.

2.3. Compensatory lengthening

Similar to deletions and insertions, shortening and lengthening processes are closely related to the syllable. A frequent process of lengthening is compensatory lengthening, where the loss of a segment is compensated by lengthening an adjacent segment. This can be accomplished by total assimilation or by vowel lengthening. For instance, in Bengali an [r] followed by a coronal consonant is optionally deleted and the consonant becomes a geminate (Hayes & Lahiri 1991). The assimilation can apply within words, across morphemes, as well as across words, the constraint being that the [rC] sequence must belong to a single phonological phrase. Some examples are given in (7).

(7) Bengali total assimilation

pɔrdɑ	pɔdːɑ	‘curtain’
por-tɑm	potːɑm	‘wear-1SG.PAST HABITUAL’
gʰɔr dʒɑmɑi̯	gʰɔdʒːɑmɑi̯	‘house son-in-law; son-in-law who lives in the house of his in-laws’

Other common instances of compensatory lengthening involve the loss of a coda consonant which leads to the lengthening of the preceding vowel. We find this in Old English with the loss of a coda nasal. If we compare the words for *five* and *tooth* in Old High German, Old English and their modern descendants, we find the pattern in (8). Since ungrammatical forms are marked elsewhere with an asterisk, the Proto-Germanic reconstructed forms will be indicated with the sign †.

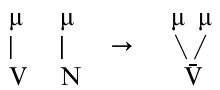
(8) Compensatory lengthening in Germanic

German	OHG	English	OE	Proto-Germanic
fünf	fimf, fumf	five	fīf	†fimfi
Gans	gans	goose	gōs	†gans

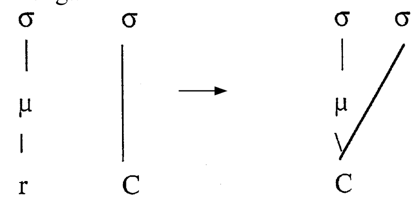
The Proto-Germanic words had a short vowel followed by a nasal consonant. The nasal has been retained in German and the vowels are still short. The loss of the nasal in English, however, has led to long vowels (which were later sometimes diphthongised) – an instance of compensatory lengthening which we can represent in a nonlinear fashion. In (9a), V and N represent any vowel or a nasal. Since long vowels are bimoraic, delinking after the loss of the nasal and reassociation, gives us the desired result. In (9b), the same effect is realised for the [r] deletion and concomitant gemination in Bengali, except that only a single mora is involved. Here the mora, which was originally linked to the [r] in the coda, is then linked to onset consonant (represented by C) in the next syllable, thus creating a geminate.

(9) Compensatory Lengthening as spreading

(a) Germanic

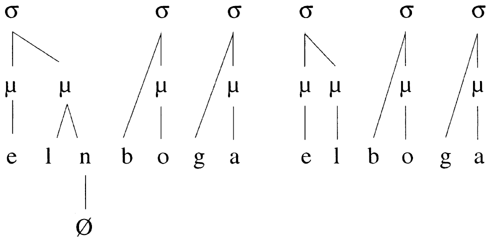


(b) Bengali



It is worth noting that when the loss of the consonant in such circumstances is closely linked with vowel lengthening, it is invariably confined to a particular syllable position, and a similar loss elsewhere in the phonology of a language will not show any concomitant lengthening. For instance, in Old English the [n] sometimes disappeared between consonants: OE *elboga* beside *elnboga* 'elbow'; OE *sæterdæg* beside *sæterndæg* 'saturday'.

(10) Loss of nasal in Old English not leading to compensatory lengthening
Compensatory lengthening as spreading onto a free mora

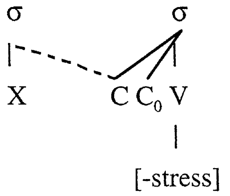


In (10) the deleted [n] is not immediately preceded by a vowel. It is in a branching coda, sharing the mora with another consonant. The loss of the nasal does not free the mora of the coda and therefore there is no spreading and no lengthening. Thus, compensatory lengthening can be viewed as maintaining the weight of a syllable.

2.4. Ambisyllabicity

The notion of ambisyllabicity has been used in two ways: as an environment for syllable-based processes and as a means of providing a coda to add weight to a syllable. The most frequently discussed phenomena where ambisyllabicity plays a role are aspiration and flapping in English (cf. Kahn 1976; Gussenhoven 1986). Both processes are governed by surface syllable structure, and hence are stress-sensitive. The ambisyllabicity results from the attraction of the first consonantal onset of an unstressed syllable to form a coda of the preceding syllable. This consonant then becomes ambisyllabic, since it belongs both to the onset and the coda of two syllables. The usual onset and coda constraints of the language apply. This procedure leading to ambisyllabicity is labelled as Extended Right Capture in Gussenhoven (1986: 130), the formulation of which is based on two different processes in Kahn (1976).

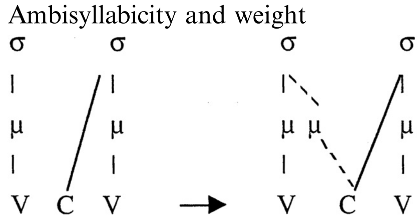
(11) Ambisyllabicity
Extended Right Capture



Ambisyllabicity accounts for a number of postlexical phonological rules of American English like flapping, aspiration, glottalization etc. Flapping weakens coronal stops [t, d] to a flap [ɾ] when they are ambisyllabic. This accounts for why the coronal stops in *later, shouting, matter* are subject to flapping, while those in *latex, bait, tail* are not. In the latter set of words, the stops are either followed by a stressed syllable (cf. *látèx*), are only in the coda (cf. *bait*), or only in the onset (cf. *tail*), and hence none of them are ambisyllabic. Similarly, aspiration is also subject to ambisyllabicity. Aspiration of voiceless stops in American English occurs when in absolute syllable onset position, and ambisyllabic consonants cannot be aspirated. This is different in British English where absolute onset position is not required for aspiration. Thus, words like *happy*, where the medial consonant is ambisyllabic, may be aspirated in British English, but never in American English. However, British English also requires ambisyllabicity as a structural possibility, since rules like weakening (which 'weaken the oral closure of obstruents' in fast informal speech, Gussenhoven 1986: 125–6) can operate on the output of aspirated consonants. However, weakening only operates on ambisyllabic aspirated consonants, and those that are in absolute onset position are exempt.

As we mentioned above, ambisyllabicity has also been argued to play a role in assigning syllable weight (cf. van der Hulst 1985 and Lahiri & Koreman 1988 for Dutch; Ghini 2001 for Miogliola, a northern Italian dialect). Under these analyses, ambisyllabicity not only allows a consonant to be part of an onset in one syllable and a coda in the other, the coda consonant also projects a mora. The representation would look as follows:

(12) Ambisyllabicity and weight



After ambisyllabicity, the phonological representation is identical to that of a geminate. However, in languages in which ambisyllabicity is invoked for syllable weight, there are no contrastive geminates (cf. also Borowsky, Itô & Mester 1984). Whether one could then assume that all such ambisyllabic consonants could be treated as geminates is a much debated topic.

The notion of ambisyllabicity has not found favour with many researchers particularly because of the dual linking of a single consonant to two syllables (Kiparsky 1979; see also Blevins 1995 for a discussion). However, the arguments in Gussenhoven (1986) are very persuasive and since dual linking has to be permitted for geminate consonants that in itself is not a sufficient argument against ambisyllabicity.

So far we have focused on two different aspects of syllable structure: syllable as a context for phonological rules and strategies to maintain preferred syllable structure and syllable weight. We now move on to discuss the role of syllable weight and its interaction with metrical stress.

3. The foot

A fundamental insight in metrical theory is that syllable weight plays a crucial role in stress assignment. As we mentioned above, the weight of a syllable usually depends on whether it has a long bimoraic vowel or whether the coda of a closed syllable contributes a mora to the syllable. Vowel quality is never taken into account where syllable weight is concerned. It would be very odd indeed, if for instance, all front vowels were treated as heavy while other vowels including long vowels were light. However, syllables are not sufficient to account for stress assignment in languages of the world. Recent theories of metrical stress argue that the foot, which is a constituent built on groups of syllables, accounts for stress. In general, syllables are considered to be grouped into metrical feet consisting of strong and weak syllables. The feet differ in terms of whether the head of the foot, i. e. the stressed position, occurs at the left or right edge. A left headed foot is known as a trochee, and a right headed foot is an iamb. We will not however, begin with the assumption that syllable weight and feet are crucial elements in stress assignment. Instead, with examples from two languages, we will trace step-by-step the motivations for assuming (a) syllables are a necessary constituent for assigning stress, (b) syllables are not enough to account for universal stress systems, (c) a fixed inventory of foot types built on syllables can delimit all stress patterns and (d) the weight of syllables play a role in building feet.

3.1. Are syllables necessary for stress?

Chomsky & Halle (1968) accounted for English stress using only a linear sequence of consonants and vowels, ignoring any hierarchical constituent like the syllable. However, referring only to a linear sequence is not enough. Let us consider the facts of the well known Latin stress rule, which has been discussed in metrical terms for a long time. The length of a vowel is indicated with a macron.

(13) Latin stress

3rd vowel from end	2nd vowel from end	
mínimus	reféctus	incū́dis
múrmuris	volúptas	relā́tus
exístimo	dēléctat	inimī́cus
adsimíliter	excérpsit	refḗcit

If asked which vowels are stressed without taking recourse to syllables, one would come up with the rule in (14):

(14) Latin stress rule based on vowels
- (i) If the penultimate vowel is long, it is stressed.
- (ii) If the penultimate vowel is followed by two consonants, it is stressed.
- (iii) Else, the antepenultimate vowel is stressed.

Such a rule, however, would cause problems for the following words.

(15) Problem cases

3rd from left	Expected 2nd from left
ténebras	*tenébras
vólucres	*volúcres
mániplis	*maníplis
látebras	*latébras

If we take the second part of the stress rule which says that if the second to last vowel is followed by two consonants it should be stressed, we have incorrect results. The solution lies in the evidence from syllabification following the sonority hierarchy. The above words are syllabified as [te.ne.bras], [vo.lu.cres], [ma.ni.plis] and [la.te.bras], as against [re.fec.tus], [vo.lup.tas] etc. Thus, the stress rule can be simplified as follows: If the penultimate syllable has a short vowel with no coda then the antepenultimate syllable bears the main stress; otherwise the penultimate syllable is stressed.

This description is very characteristic of stress rules. Syllables with long vowels or with a coda consonant pattern together. And now we come to syllable weight. As we have seen before, this division is descriptively characterised as heavy syllables versus light syllables. The Latin stress rule can then be stated as:

(16) Latin stress rule in terms of syllable weight
   (i) If the penultimate syllable is heavy, it is stressed.
   (ii) Else, the antepenultimate syllable is stressed.

3.2. Are syllables enough for stress?

So far we have seen that a linear string of consonants and vowels is not enough to account for stress. Instead we require the notion of syllables, and particularly syllable weight. But is syllable weight enough to capture stress facts of various languages? That is, is it always the case that stress assignment can be characterised in terms of heavy and light syllables? The answer is no. Let us look at a more complicated case – Creek, a Muskogean language. The data in this paper comes from Haas (1977). Haas describes Creek as having tonal accent, which falls on a 'key syllable' (p. 195). There can be more than one 'key' syllable, each one being 'one step lower than the preceding' one (p. 196). The tones themselves can be level, falling or rising. Assuming that the key syllables are the prominent syllables indicating main and secondary stresses, Creek provides us with a rich source of data. Further data is given in Hayes (1995: 64–65). Consider the following facts:

(17) Creek data (length is indicated with the diacritic [:])

pocóswa	'axe'
cofí	'rabbit'
acolakí	'old timers, elders'
osáhwa	'crow'
ahicitá	'one to look after'
cá:lo	'trout'
sókca	'sack'
famí:ca	'canteloupe'

If we assume that all consonant clusters are broken up into onset and coda, and that closed syllables are heavy, Creek stress can be described as follows:

(18) Creek stress – first approximation
   (i) If the penultimate syllable is heavy, it is stressed.
   (ii) Else, the last syllable is stressed.

So far, the Creek data look quite similar to Latin, the only difference being that in Creek if the penult is not heavy the last syllable is stressed. Now let us consider a few more words.

(19) Further data in Creek

ifóci	'puppy'
imahicíta	'one to look after for (someone)'
itiwanayipíta	'to tie each other'
acahaŋkatíta	'one to count me'

In the above words, the penultimate syllable is light, but nevertheless it is stressed. According to our preceding assumption, the last syllable should have borne stress. Perhaps we can salvage the analysis by the following statement:

(20) Creek stress – second approximation
   (i) If the penultimate syllable is heavy, it is stressed.
   (ii) If the penultimate syllable is light, stress the final or penultimate whichever is even-numbered, counting left to right.

Unfortunately this does not solve the problem. Consider the following words:

(21) More data from Creek

aktopá	'bridge'
wa:kocí	'calf'
hoktakí	'women'
iŋkosapitá	'one to implore'

Clearly, our previous rules will not suffice. In all the words, the penult is light, but the syllable that is stressed is not even-numbered counting left-to-right. What we need to do is not to start counting from the beginning of the word, but from the rightmost heavy syllable. The stress rule could then be described as follows:

(22) Creek stress – third approximation
(i) If the penultimate syllable is heavy, it is stressed.
(ii) If not, examine the maximum string of light syllables at the end of the word.
(iii) Within this string, stress the rightmost even-numbered syllable counting left-to-right.

We go through two examples following the steps elaborated above.

(23) Deriving Creek stress – third approximation

	iŋkosapitá	acahaŋkatíta
(i)	–	–
(ii)	iŋ (ko sa pi ta)	acahaŋ (ka ti ta)
(iii)	*	*
	1 2 3 4	1 2 3
	iŋ (ko sa pi tá)	acahaŋ (ka tí ta)

This description is not particularly illuminating. Clearly we are missing a generalisation. If the penult is not heavy, it is not syllable counting that gives us the right answer, but some constituent which groups syllables together. Such a constituent in poetic meter is known as a foot, and in the next section we discuss the universal inventory of feet that have been suggested for natural language.

3.3. Inventory of feet

Hayes (1995) argues that there are three basic foot types used in linguistic systems universally: a syllabic trochee, a moraic trochee, and an iamb. The syllabic trochee groups any two syllables together regardless of their weight. A moraic trochee and an iamb are weight sensitive. These three foot types are given below. The foot is demarcated between parentheses and the strong and weak branches are indicated by a [x] and a dot [.] respectively.

(24) Trochees and Iambs
(a) Syllabic trochee (weight insensitive)
(x .)
σ σ
(b) Moraic trochee: left headed (constructed over two light syllables or one heavy syllable)
(x .) (x)
σ σ σ
| | /\
μ μ μμ
(c) Iamb: right headed (construed over two light syllables, a light plus a heavy syllable, or one heavy syllable)
(. x) (. x) (x)
σ σ σ σ σ
| | | /\ /\
μ μ μ μμ μμ

Although the moraic trochee and the iamb are both weight sensitive (i. e. the weak branch cannot be heavier than the strong branch), under Hayes' analysis these two feet are asymmetric. Under this system, an iamb may have a [L(ight) H(eavy)] sequence, but a trochee is not permitted to have a branching head. The way stress assignment works is as follows. A string of syllables are parsed into feet going from left-to-right or right-to-left. The last foot on the left or the right is assigned main stress: End Rule (left/right). Thus, main stress is always at an edge of a word, edge being defined by foot structure and not by syllables or vowels. To assign stress, we therefore require the following parameters:

(25) Stress assignment
(a) Foot type
(b) Direction of parsing
(c) End Rule

We illustrate this first with the most straightforward foot type, namely the syllabic trochee, which is weight insensitive. The syllabic trochee groups syllables together regardless of their internal structure. The analysis is from Hayes (1995: 62–63).

(26) Syllabic trochee (Pintupi, a Pama-Nyungan language of Australia)
Foot construction: Left to Right
Main stress: End Rule Left (indicated with X)

(X)	(X)	(X)	(X)
(x .)(x .)	(x .)(x .)	(x .)(x .)(x .)	(x .)(x .)(x .)
σ σ σ σ	σ σ σ σ σ	σ σ σ σ σ σ	σ σ σ σ σ σ σ
máɭawàna	púɭiŋkàlatʲu	tʲámulìmpatʲùŋku	ʈíɭirìŋulámpatʲu
'through from behind'	'we (sat) on the hill'	'our relation'	'the fire for our benefit flared up'

Let us now turn back to Creek and investigate which of the foot types would be appropriate to account for the entire set of data. Clearly syllable weight plays a role since the penultimate syllable is stressed only when it is heavy. The End Rule appears to be on the right, since stress falls always towards the right edge of the word. Now we need to determine the direction of parsing and whether the foot type is a moraic trochee or an iamb. The syllabic trochee cannot be considered since it is quantity insensitive. The decision is not a difficult one since in our third approximation we saw that when a sequence of light syllables occur at the end of a word, the rightmost even numbered syllable can get stressed. As a result final light syllables may bear stress and this is not possible for a trochee. Thus, if the foot inventory is indeed sufficient, then the foot type must be an iamb.

The final decision regarding stress assignment must be the direction of parsing. Again in the last approximation, if the penult was not stressed, the grouping of syllables into a larger constituent began after the last heavy syllable. Hence, the parsing must be from left-to-right. Following Hayes (1995), applying these parameters to Creek we obtain the following structures:

(27) Stress assignment in Creek: final version

Syllable weight:	Long vowels and closed syllables are heavy
Foot type	Iamb
Foot construction:	Left to Right
Main stress:	End Rule Right

```
( X)   ( X )      (      X)       (     X )       ( X   )
(. x)  (. x)      (. x)(. x)      (. x)(. x)       (. x)
μ  μ   μ μ μ      μ  μ  μ μ       μ μ  μ μ μ       μ  μμ  μ
co fí  i f ó c i  a co la kí      i mahi cí ta     fa mí: ca
(     X)          (           X)        (           X )
(x)(. x)          (x)(. x)(. x)         (. x)(x)  (. x)
μμ  μ μ           μμ  μ μ μ  μ          μ μ μμ μ μ  μ
wa: ko cí         iŋ ko sa pi tá        a ca haŋ katí ta
```

Thus, although syllables may provide an adequate description for stress patterns in some languages, they are not sufficient to account for the complicated systems like Creek. Once we introduce a larger constituent grouping syllables together into feet, the analysis of the stress pattern becomes very simple.

In addition to the three basic foot templates, it is necessary to invoke the notion of extrametricality to understand some other stress patterns. Syllables or segments (usually consonants) at right edges are often extrametrical; that is, they behave as if they do not exist for footing and, therefore, not for stress. Thus, there are four parameters to be taken into account: foot type, extrametricality, direction of foot parsing and the end rule. In the two following examples taken from Hayes (1995) we see instantiations of the moraic trochee with and without extrametricality (cf. (28)).

This brings us back to Latin stress. Recall that in Latin, stress fell on the penultimate syllable if it was heavy. Otherwise the antepenultimate syllable bore stress regardless of weight. We can now analyse Latin in the following way (cf. (29)).

The moraic trochee along with the extrametricality does away with the oddity of the syllable based description which required that syllable weight was responsible for attracting stress on to the penultimate syllable but not for the antepenultimate syllable. The antepenult could be stressed regardless of syllable weight; it depended on the lack of weight of the penult. In the foot based analysis, the explanation rests on the fact that the antepenult and the penult together can make up a single foot if both are light.

The inventory given above excludes the possibility of asymmetric moraic trochees which are the mirror images of iambs. However, others like Dresher & Lahiri (1991), Lahiri & Dresher (1999, for Germanic), Jacobs (1989, 2000, for Latin), Kager (1989, for English) have claimed that asymmetric trochees incorporating [H L] sequences are necessary as well. For instance in Latin, using an asymmetric trochee would mean that words like *murmuris* would be parsed into feet as ([mur. mu] ⟨ris⟩). The traditional trochee is, in fact, asymmetric (cf. Hayes 1981). Although we are not in a position here to exhaustively compare these various proposals, while discussing the foot based phonological

(28) Moraic trochees with and without extrametricality

Moraic trochee (with extrametricality)

Cairene Arabic (No classical words are considered)

Syllable weight:	Long vowels and closed syllables are heavy
Extrametricality:	Final consonant of a word (indicated by ⟨ ⟩)
Direction of Parsing:	Left to Right
Main stress:	End Rule Right

(X)	(X)	(X)	(X)	(X)	(X)
(x)	(x)	(x)	(x)	(x) (x.)	(x .)(x .)
μμ μ	μ μμ	μ μμ	μ μμ μ	μ μμ μ μ	μ μ μ μ
be:tá⟨k⟩	gɑtó:	kɑtáb⟨t⟩	mudárri⟨s⟩	mudɑrrísi⟨t⟩	kɑtɑbítu
'your (M.SG.) house	cake'	'I wrote'	'teacher'	'teacher (f. construct)'	'she wrote it (M.)'

Moraic trochee (Wargamay: Pama-Nyungan language of Australia)

Syllable weight:	Long vowels are heavy
Direction of parsing:	Right to Left
Main stress:	End Rule Left

(X)	(X)	(X)	(X)
(x)	(x .)(x .)	(x .)	(x .) (x .)
μμ μ	μ μ μ μ	μ μ μ	μ μ μ μ μ
mú:bɑ	gíɟawùlu	gɑgárɑ	ɟuɽágaymìri
'stone fish'	'freshwater jewfish'	'dilly bag'	'Niagara-Vale-from'

(29) Latin stress revisited

Syllable weight:	Long vowels and closed syllables are heavy
Extrametricality:	Final syllable
Direction of Parsing:	Right to Left
Main stress:	End Rule Right

(X)	(X)	(X)	(X)
(x)	(x) (x)	(x .)	(x)
μ μμ μμ	μμ μμ μμ	μ μ μμ	μμ μ μμ
re féc ⟨tus⟩	dē léc ⟨tat⟩	vó lu ⟨cres⟩	múr mu ⟨ris⟩

(30) Constraining gemination in OE

Gemination blocked:

(x .)		(x .)	
([μμ] μ)	[μμμ] μ	([μ μ] μ)	[μ μμ] μ
H L		L L L	
wī tje > *wītte		æ þe lje > *æ þel le	
'punishment DAT. SG.'		'noble DAT. SG.'	

Gemination permitted

(x .)	(x) (x .)	(x)	(x .)
([μμ] μ) μ	([μμ]) ([μμ] μ)	([μ μ])	([μμ] μ)
H L L	H H L	L L	H L
wē ste nje >	wē sten ne	cy nje >	cyn ne
'desert DAT. SG.'		'race DAT. SG.'	

processes, we will draw on evidence from segmental rules and stress in Germanic to provide support for asymmetric trochees.

3.5. Foot-based phonological processes

Phonological processes can be sensitive to the foot. The foot relevant for Germanic was a resolved moraic trochee, which is essentially an asymmetric trochee, where the head must branch. An example of a foot based process is West Germanic gemination, which is simply a process by which all consonants are doubled when followed by a front glide /j/. It is constrained only when the head becomes trimoraic. The following Old English nouns illustrate gemination, where the head of the foot is circumscribed by square brackets (cf. (30)).

The form *$w\bar{\imath}tte$ is impossible because the head cannot be trimoraic. Similarly, **æþelle* is disallowed because the weak branch of the head is strengthened and again the head becomes trimoraic. Not just strengthening processes, but deletions can also be sensitive to foot structure. For instance, high vowels in Old English were deleted in the weak branch of a foot (Dresher & Lahiri 1991). In the following examples the underlined vowels are deleted (cf. (31)).

The [u] in *lofu* is not deleted because it is within the head. In contrast, in *wordu* and *færeldu*, the [u] is in the weak branch of the foot, and hence is deleted. Note that a trimoraic head in *færeld* is permitted because there was no choice to begin with. However, a process like gemination is prohibited from creating one as we saw in the case of **æþelle*. The foot also accounts for stress: the head of the foot in each word bears main stress.

3.6. Minimal word and the foot

The phonological word is the next constituent above the foot. Just like the syllable and the foot, most languages adhere to constraints which try to maintain a 'minimal word'. Most languages have a minimal word requirement which is closely related to a foot. The minimal word must be at least a foot, or two syllables, or bimoraic, or some other prosodic constraint. Our interest here is primarily on the correlation between minimal word requirements and metrical coherence. We will, therefore, briefly illustrate the role of the minimal word in prosodic phonology and morphology.

Vowels are often lengthened to meet a minimal word requirement. In Bengali, for instance, a vowel in a monosyllabic word is always lengthened unless the vowel nucleus has a diphthong (Fitzpatrick-Cole 1994).

(32) Vowel lengthening in Bengali

a.	tʃɑː	'want, ask for 2P.FAMILIAR IMPERATIVE / tea'
b.	tʃɑ+i > tʃɑi̯	'want, ask for +1P. PRESENT'
c.	tʃɑː=i	'tea=ONLY'
d.	nɑːk	'nose'
e.	nɑk+i	'nose+ADJECTIVAL SUFFIX / nasal'
f.	nɑːk=i	'nose=ONLY'

The morpheme /tʃa/ can be both a verb root 'to want' or the noun 'tea'. The '+' boundary indicates a suffix while the '=' sign marks a clitic. The different suffixation and cliticised forms show the vowel length alternation. It should be noted that Bengali does not have contrastive vowel length. At first glance the lengthening of the vowel in (32 c, f) seems to be a counterexample to the minimal word requirement. In fact, (32e) shows that a derived word which is disyllabic does not lengthen a vowel similar to the monosyllabic word in (32b). However, the final vowel in (32f) is not a suffix but a clitic, just as in (32c). Clitics are added to a word and hence, the minimal word requirement must be met before the clitic is added. We see a difference in (32b) and (32c) where the former is a suffixed word and the resulting diphthong satisfies the minimal word requirement. In (32c), however, the final vowel is a clitic and again, the initial vowel is lengthened.

(31) Foot based syncope in OE

(X)	(X)	X)	(X)
(x .)	(x .)	(x .)	(x .)
([μμ] μ) μ	([μμ] μ)	([μ μμ] μ)	([μμ] μ) μ
H L L	H L	L H L	H L L
hēa fu̲ de	wor du̲	fæ rel du̲	clī we nu
hēafde	*word*	*færeld*	*clīwenu*
'head'	'word'	'journey'	'ball of thread, clew'
DAT. SG.	NOM.PL.	NOM.PL.	NOM. PL.
(X)	(X)	(X)	(X)
(x .) (x)	(x .)	(x)	(x)
([μμ] μ) [μμ]	([μ μ] μ)	([μ μ])	([μ μμ])
H L H	L L L	L L	L H
hēa fu̲ des	we ru du̲	lo fu	su num
hēafdes	*werud*	*lofu*	*sunum*
'head'	'troop'	'praise'	'son'
GEN.SG.	NOM.PL.	NOM.PL.	DAT.PL.

These facts are not unusual. Many languages, including Germanic languages like English, Dutch and German, also have minimal word requirements. No content word of these languages can end with a single lax vowel: *[sɪ] or *[bɛ] would be completely impossible words in these languages. They should either have a long vowel as in *sea/see* [si:], or should be closed as in *sit* [sɪt]. The research of McCarthy & Prince (1990) demonstrates that the minimal word plays an important role in the prosodic morphology of languages. In their discussion of this phenomenon in Arabic, they give examples of a small number of nouns (usually related to body parts and kinship terms) which disobey the bimoraic, minimal word requirement (final consonants are extrametrical and hence do not count for weight): [ʔab] 'father', (ʔax] 'brother' etc. However, when these nouns serve as the basis of regular word formation processes, they acquire an extra consonant, thus fulfilling the minimality requirement: [ʔab] 'father', but [ʔabaw-iy] 'paternal'; cf. [maṣr] 'Egypt', [maṣr-iy] 'Egyptian'.

Minimal word requirements are also often reflected in blocking the application of rules that may shorten a word beyond the minimum. For instance, Lardil has a disyllabic word minimum. Apocope applies freely to trisyllabic or longer stems, but it is blocked in disyllables since it would shorten a word beyond the acceptable minimal word requirement (Kenstowicz 1994). In the following examples we see that the final stem vowel is always deleted in the uninflected form, except in the last two words which are disyllabic.

(33) Lardil apocope

uninflected	inflected	gloss
yalul	yalulu-n	'flame'
mayar	mayara-n	'rainbow'
karikar	karikari-n	'butterfish'
mela	mela-n	'sea'
wiṭe	wiṭe-n	'inferior'

Minimality constraints can also add a mora or a syllable when the base has less than the weight required to satisfy the minimum word requirements. Such a process is also evident in Lardil (Kenstowicz 1994).

(34) Addition of a mora in Lardil

uninflected	inflected	gloss
kentapal	kentapal-in	'dugong'
yaraman	yaraman-in	'horse'
yaka	yak-in	'fish'
ṭera	ṭer-in	'thigh'

In the last two examples, the base forms are not disyllabic since the suffixation shows that they are consonant final stems (cf. the examples above). However, to meet the minimal word requirement, a final vowel is added to the base stem or the uninflected form to ensure that it surfaces as disyllabic.

3.7. The foot and typological premises

How do the above analyses fit into the usual typological premises made when referring to stress? We have argued that stress is not a feature on a vowel, but rather is the linguistic manifestation of rhythmic structure. As such, although one could state that a given syllable in a word bears the main stress, this is not the best way to account for stress rules. An alternative and better way is to construe stress placement as the parsing of a word into metrical feet. This does not preclude the possibility that there are languages with fixed main stress either on the initial syllable or on the final syllable. Out of 300 languages, Hyman (1977) noted that 114 languages have initial stress, 97 final stress, 77 penultimate stress and only 12 have stress on the second syllable. Such a statement, however, says nothing about how secondary stress could work. Under a metrical foot analysis, a language with final syllable stress could easily have either a moraic trochee or an iamb, if all final syllables happened to be heavy and parsing was from right to left. Predictions for secondary stress, however, would be different. Consider the following hypothetical example.

(35) Final syllable stress: iamb or trochee?

Parsing Right to Left, Moraic trochee, End Rule Right

```
(                  X)
  (x) (x  .) (x)   (x)
σ̆  σ̄  σ̆  σ̆  σ̄  σ̆  σ̄
```

Parsing Right to Left, Iamb, End Rule Right

```
(                  X)
(.  x)   (.  x)(.  x)
σ̆  σ̄  σ̆  σ̆  σ̄  σ̆  σ̄
```

The final syllable obtains stress in both instances. But parsing into metrical feet predicts that the third syllable from the beginning could bear secondary stress only if the foot is a moraic trochee, and not if it is an iamb. Thus, broad typological statements such as main stress is final, can be misleading. This does not mean that stress cannot be fixed regardless of the type of syllable. Usually this happens if stress, or rather the metrical parameters, are in some way morphologically governed. For instance, with English productive affixation like *béautiful*, stress is insensitive to rhythmic patterns. Stress falls on the antepenultimate syllable because it happens to be the initial syllable of the stem. Another way of looking at it is that in derived adjectives the final syllable is extrametrical. Morphological effects of stress can be also found when certain suffixes always bear stress as in German *-ier*, (e.g. *Juwelíer*), or English *-ee*, (e.g. *devotee*). However, even with morphologically stress, the window within which stress falls is usually constrained. Hence, when typological correlations are drawn with respect to stress, it is worthwhile to be more precise about the rhythmic organisation and the type of foot. We will discuss this in more detail in § 4.

In this section, we have covered a wide range of facts involving metrical structures. We have briefly discussed various phonological processes sensitive to metrical structure, including shortening and lengthening processes, segmental alternations, repair strategies for preferred syllables, etc. The central goal was to show that along with stress assignment, phonological rules do not only operate in local segmental contexts, but that hierarchical structures like syllables and feet also constrain representations and processes.

4. Typology and Metrical Structures

Having established the necessity for metrical constituents like syllables and feet, we are now in a position to address issues of typological implications. In the preceding sections, we outlined different types of syllable structures and feet which languages appear to have. We have not discussed, however, any particular correlations between such structures nor any possible relationship between the existence of different types of metrical structures within a given language. For instance, is it possible that all types of feet coexist in a single language? Would it be possible to infer the preferred syllable structure of a language if its type of foot is known? Are there any implications to be drawn from preferred metrical structures of language and the types of rules that are permitted? Such questions are rarely if at all addressed within phonology. We will draw attention to three possible typologically interesting issues: (a) the relevance of metrical constituents outside phonology, (b) the coherence of metrical units within a given language, and (c) correlations drawn between metrical constituents and other phonological and morphological patterns.

4.1. Metrical constituents outside phonology

Research in prosodic morphology (cf. McCarthy & Prince 1986, 1993) indicates that metrical categories required in phonology are the same that are necessary for morphological processes like reduplication. Typologically, therefore, the implication is that if a new category is found to be necessary to describe either stress or any other phonological process, it ought to be found relevant for a morphological process as well. The following two examples support the view that both syllables and feet are relevant for morphology.

In Mokilese, the progressive is expressed by a form of reduplication (Harrison & Albert 1976; McCarthy & Prince 1986). Samples of the data are given below.

(36) Mokilese progressive

a.	pɔ.dok	**pɔd**-pɔ.dok	'plant'
b.	pa	**paa**-pa	'weave'
	di.ar	**dii**-di.ar	'find'
c.	sɔɔ.rɔk	**sɔɔ**-sɔɔ.rɔk	'tear'
	caak	**caa**-caak	'bend'
d.	an.dip	**an.d**-an.dip	'spit'
	o.nop	**on.n**-o.nop	'prepare'

At first glance, it seems as if the progressive is formed by some sort of a prefix which is equivalent to a syllable. However, the nature of the syllable differs for each word type. The reduplication is essentially the prefixation of a bimoraic syllable [$\sigma_{\mu\mu}$]. In (36a) the initial syllable of the stem is monomoraic and hence the following onset is included to form the prefix. In (36b), where the stem is monosyllabic or where the second syllable has no consonantal onset, the vowel is lengthened to satisfy the bimoraic requirement. In (36c) the bimoraic requirement is met by simply taking the initial long vowel. The most interesting case is (36d) where [an] or [on] would surely have met the bimoraic requirement. However, the output form would then have been *[on-onop], which would then be syllabified as *[o.no.nop] and the initial prefix would be monomoraic. Thus, the constraint is that the morphological prefix must be an entire bimoraic syllable, and simultaneously the onset of the next syllable must be maximised. For the latter, if the stem begins with a vowel, either the onset of the second syllable is used even if it has to be doubled.

In the next example we see that a morphological process can be sensitive to a foot. The data is from Ulwa (McCarthy & Prince 1990).

(37) Ulwa construct state (3 SG. POSSESSED)

a.	kii	(kii)-ka	'stone'
	bas	(bas)-ka	'hair'
	sana	(sana)-ka	'deer'
	sapaa	(sapaa)-ka	'forehead'
	amak	(amak)-ka	'bee'
b.	suulu	(suu)-ka-lu	'dog'
	baskarna	(bas)-ka-karna	'comb'
	siwanak	(siwa)-ka-nak	'root'
	anaalaaka	(anaa)-ka-laaka	'chin'
	karasmak	(karas)-ka-mak	'knee'

The data in (a) is straightforward – a suffix [ka] is added to the stem. However, the data in (b) shows that the [ka] behaves like an infix and the way in which the stem is divided up appears to be different in each case. In the first two examples, the [ka] is added to the first syllable, while in the others it is added after two syllables. If we compare the two sets, we can see that [ka] is added after two syllables only when the first syllable is light and the second is heavy or light – [a.nɑɑ] – but not, when the first syllable is heavy and the second is light as in [suu.lu]. Thus, it is not a syllable which is the relevant constituent but a foot and a typical iamb $[\sigma_{\mu}\sigma_{\mu\mu}]$. The morphological process is thus the following: add the suffix [ka] to the leftmost iambic foot.

Thus, the metrical constituents including syllables, feet and minimal word that are used for the description of stress and are sensitive to other phonological processes are argued to be the same for morphological processes. The obvious question that now comes to mind is whether within a given language, the same metrical constituent is used both for stress and other phonological processes, and in addition whether morphology and phonology share precisely the same type of constituent as well. We now turn to these issues.

4.2. Metrical coherence

Typically languages adhere to the same foot for stress as well as for other phonological processes. A language following such a principle would be judged as being metrically coherent and arguably such a language would also be easier to learn (cf. Dresher & Lahiri 1991). One could also extend the principle of metrical coherence to morphology as well. As Hayes (1995) points out, usually in any given language, the kind of foot used for stress is the same as that used in morphology. We will address this issue first from a purely phonological perspective and then briefly address the notion of coherence within prosodic phonology and morphology.

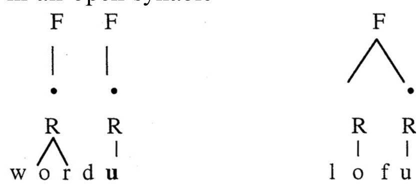
4.2.1. Coherence in stress and phonological processes

There is nothing discussed in the earlier sections that suggests that metrical coherence is a must or even preferred. One could imagine that metrical structures are counting devices such that one type of foot is used for stress and another could be used as the context for other phonological rules. For instance, Keyser and O'Neill (1976) suggested that in Old English, stress required an initial quantity insensitive left-headed foot while a quantity sensitive right-headed iamb was necessary to account for the rule of high vowel deletion, where R = rhyme

(38) Feet in Old English following Keyser and O'Neill

a. Word stress: left-headed unbounded foot

b. High vowel deletion: following a right-headed quantity sensitive foot in an open syllable



Under such an analysis, headedness is completely arbitrary. For the purposes of stress, the left head of a foot is the strongest, while for syncope, the right head of the foot is strong. However, such a system would be incredibly difficult for the language learner to acquire. As shown in § 3.5., this analysis is not the only one that could account for the data. Germanic is essentially metrically coherent, and both stress and deletion of high vowels can be accounted for by a single foot type. Other languages have similar properties. One example is Unami, an Eastern Algonquian language described in Hayes (1995: 211−213) based on Goddard (1979). Hayes argues that stress in Unami is accounted for by forming iambs left to right with foot extrametricality and End Rule Right. Moreover, voiceless consonants other than [h] are geminated after a strong vowel which would be the head of a foot.

(39) Unami stress and gemination
(X)
(. x) ⟨(. x)⟩
nə mə t əmeː 'I follow a trail'
→
(X)
(. x) ⟨(. x)⟩
nə mə **tt** əmeː
Compare/mətəmeːw/ → [mətə́meː(w)] 'he follows a trail'

In general, phonological rules sensitive to foot structure are usually deletion, weakening or strengthening processes as we have seen in earlier sections. In most instances, they apply to either repair metrical structures or are invoked to build preferred structures. Therefore it is not surprising that the foot required for stress and other phonological processes would be the same. What is more interesting is the notion of metrical coherence outside phonology to which we turn next.

4.2.2. Metrical coherence and morphology

As we mentioned earlier, the set of metrical constituents that are relevant for phonology are the same that are used in prosodic morphology. For instance, often, suffix allomorphy is governed by a metrical unit. In Dutch, the nominalising suffix {-aar} adds only to bisyllabic verbs, while {-er} is added to monosyllabic verbs: *luister* 'to listen' > *luister-aar* 'listener'; *bel* 'to ring' > *bell-er* 'ringer'. Booij (1997) argues that the underlying reason for this allomorphy is to maintain a proper trochee on the surface. The form **luisterer* would not form a proper trochee while *luisteraar* ends up as two acceptable feet.

Our interest here is whether the type of foot necessary for a language's morphological system is the same as that required for stress. That is, can we extend the notion of metrical coherence to morphology as well. It appears that almost always the foot used for stress is the same as that used for prosodic morphology. One example is Manam (Austronesian language, spoken in New Guinea). The description of stress is given in Kenstowicz (1994: 614, 659) and the morphological process of reduplication is described in McCarthy & Prince (1986: 39).

(40) Manam Stress and Reduplication

a.	mó.tu		'island'
	ma.nám		'Manam island'
	wa.rí.ge		'rope'
	ma.la.bóŋ		'flying fox'
	ʔi-po.a.sa.gé.na		'we are tired'
b.	láʔo	laʔo- láʔo	'go'
	moíta	mo-ita-íta	'knife'
	malabóŋ	mala-bom-bóŋ	'flying fox'

Stress is assigned by a moraic trochee parsed from right to left. The reduplication also clearly refers to the same foot. However, there is nothing inherent about metrical structures that requires the same foot to be used for phonology and morphology. One glaring counterexample in the literature is Axininca Campa. While stress is iambic (Payne 1981; Spring 1990a; McCarthy & Prince 1993), there is disagreement in the literature about the foot type(s) needed for morphology (Spring 1990a, 1990b; McCarthy & Prince 1993). For instance, Spring (1990b) claims that while the foot necessary for genitive allomorphy is the moraic trochee, the foot for verb reduplication is the iamb.

However, other analyses of Axininca Campa suggest that the situation is not as complicated as suggested by Spring. While the distinctive base of both genitive allomorphy and reduplication is characterised by a bimoraic foot, the reduplicant is a different constituent with a strong tendency towards disyllabicity. Metrical coherence may be maintained for Axininca Campa if the bimoraic foot is regarded as 'minimal iamb', while the disyllabic foot is considered to be a 'maximal iamb'. Only a small sample of the crucial data is presented to show the analysis (cf. (41)).

The descriptive generalisation for the genitive allomorphy is that if the stem contains only two moras, the suffix /ni/ is taken, otherwise the suffix is /ti/. This led Spring (1990b) to suggest that the genitive allomorphy was sensitive to a trochee. However, a bimoraic foot could be both a trochee as well as an iamb, the difference being the headedness. Since there is no evidence of headedness in this context, the analysis could just as well be that if the foot is a minimal iamb, the suffix is /ni/. The verb reduplication is more straightforwardly an iamb. If the non-prefixed stem is a single syllable, the reduplication includes the prefix. That the reduplicant

(41) Axininca Campa

a. Stress (following McCarthy & Prince 1993, Spring 1990a, 1990b): Iamb, Left to Right, Final light syllable extrametrical.

(ki.mí).ta.⟨ka⟩	'maybe'
(o.cí).(to.mó).⟨ko⟩	'monkey'
(i.ráa).(wa.ná).⟨ti⟩	'su caoba'

b. Genitive allomorphy (data Spring 1990a)

/sima/	no-sima-ni	'my fish'
/mii/	no-mii-ni	'my otter'
/sawoo/	no-sawoo-ti	'my cane'
/maini/	no-maini-ti	'my bear'
/cokori/	no-cokori-ti	'my armadillo'

c. Verb reduplication-prefixed pattern (Payne 1981)

/kiNtʰa/	noŋ - kintʰa - kintʰa	'tell'
/kawosi/	noŋ - kawosi - kawosi	'bathe'
/naa/	no - naa - nonaa	'chew'
/na/	no - na - nona	'carry'
/osaNpi/	n - osampi - sampi	'ask'
/apii/	n - apii - napii	'repeat'

is a canonical iamb is seen in the last example. Normally, the stem initial vowel is not reduplicated as in [n-osampi-sampi]. However, when the stem itself is disyllabic as in /apii/, the reduplication does not ignore the initial vowel. The reduplicated form is [n-apii-napii] and not *[n-apii-pii] showing that there is strong preference to have a canonical iamb if possible (Black 1991; Loewe 1996).

Thus, even in a complex set of interactions as in Axininca Campa, there is no clear evidence that entirely different feet are required for morphology and phonology. Since in most instances, morphology requires either a disyllabic or bimoraic foot with no clear headedness preferences, or just a minimal word (cf. § 3.6.), the stress facts do not clash with morphological processes (cf. McCarthy & Prince 1990 for various examples). It seems, therefore, that metrical coherence can be extended to morphology as well.

5. Universals, implications and correlations

In the typological literature, little has been said concerning the details of metrical constituents and implications thereof. The focus of attention has been either to associate morphological types like agglutination vs. flection with stress-timing or syllable-timing, or with general rhythmic patterns like iambic and trochaic with possible syllable types and types of clusters. For example, Lehmann (1973, 1978) claims that agglutinating languages correlate with simple syllable structure, pitch accent and mora-counting, while flective languages have complex syllable structures, stress accent with reduction of unstressed syllables, and syllable-counting. Plank (1998) provides a detailed account of the various attempts in the literature to draw correlations within phonological constituents as well as between phonological and morphological categories. The results are highly unsatisfactory, and as Plank points out, often contradictory. Our interest here is primarily on metrical constituents and we will discuss briefly some of the proposals put forward in the literature.

Donegan & Stampe (1983) argue that rhythmic properties determine different morphological types and syntactic word order. The central notion is that since accent is the only factor which is pervasive through all levels of language, it is the only meaningful determinant in connecting the different levels of language. For instance, there is a direct relationship between word order and phrasal accent. In a sentence, the operand or head is given information, while the operator or modifier is asserted and hence bears the main accent, regardless of the relative order of the two parts. They make a very strong claim that rising (final) vs. falling (initial) phrase accent is the primary variable and that operand/operator order follows from it. In fact, primary phrase accent determines more than just word order: syllable and word canons, phonological segments, as well as timing are closely related. For instance, initial phrase accent correlates with trochaic word accent, syllable-timing or mora-timing, a preference for (C)V(C) syllables and geminate clusters. Final phrase accent and iambic word accent goes hand in hand with stress-timed languages, with (C)V or (C)(C)V(Glide)(C) syllables and non-geminate clusters. The trochaic pattern goes with agglutinative morphology while the iambic pattern goes with more flective morphology.

Gil's approach to prosodic typology is also based on rhythm (Gil 1986), but it seems to make somewhat opposite predictions. Although Gil agrees with Donegan & Stampe that trochaic rhythm patterns with syllable timed languages and iambic rhythm with stress timed languages, he supports the view that agglutinative languages prefer iambic rhythm, are stress timed, have a high consonant-vowel ratio, and have a simple syllable structure. In contrast, flective languages prefer trochaic rhythm, are syllable-timed, have complex syllable structure, and have a low consonant-vowel ratio. Thus, the correlation between agglutinative/flective morphology with trochaic/iambic rhythm is the opposite. Gil (1987) however, lays less emphasis on the typological prominence of phrasal rhythm, since, he states, most languages tend to have iambic patterns on the phrase and clause level. What he had in mind is perhaps that an intonation phrase is invariably divided up into HEAD + NUCLEUS where the nucleus contains the most important information (cf. Hayes & Lahiri 1991). However, it is not the case that within the nucleus, languages always prefer iambic patterns. Banking on the difference between iambic and trochaic rhythm within phonological phrases, Nespor, Guasti & Christophe (1996) argue that language learners correlate this difference with the branching nature of syntax. Thus, a trochaic rhythm correlates with left-branching structures and an iambic rhythm with right-branching structures. The syntactic branchingness correlates with heaviness. Crucially, the authors make no attempt to link word stress with phrasal stress, the former being an independent variable.

In sum, in the attempts to draw correlations between rhythm (which is of interest to us since it is related to metrical structures) and other phonological, morphological, and syntactic structures, there are two major approaches. First, a correlation is established between phrasal rhythm and syntactic structure (Donegan & Stampe 1983, Nespor, Guasti & Christophe 1996), but Gil (1987) views phrasal rhythm as not being a dependable variable to support typology. The difference between Donegan & Stampe and Nespor et al. is that the former connect phrasal rhythm with word rhythm, while for the latter word stress is an independent variable.

Second, a correlation is made between word rhythm and other phonological constituents like syllable structure, stress/syllable timing, and morphological structure. Here, as we mentioned earlier, Donegan & Stampe, and Gil sometimes make opposite predictions. For instance, Donegan & Stampe associate iambic rhythm with complex syllable structure while Gil has it the other way around. Other authors who have attempted these correlations do not always agree either (see Plank 1998: 216 for details). What then do these typological correlations mean? We will concentrate on the correlations drawn on the basis of word rhythm since this has been the primary focus in this paper.

The authors (Donegan & Stampe, and Gil) are basing their hypotheses and analyses on samples of data from which they have observed certain patterns. But the conclusions do not appear to be based on detailed properties of metrical constituents as we have discussed so far. It is true that if a language prefers an iambic foot, it is almost certain that it would have long vowels since an iamb is by nature asymmetric in quantity. However, there is nothing to prevent a language from preferring an iambic foot where the quantity is determined solely on the basis of closed vs. open syllables. But more important, preferring an iambic word rhythm, does not necessarily mean that the language prefers stress to be at the right edge of a word, which is what the correlations seem to imply. Whether the right or the left edge of a word bears main stress depends on the End Rule and not only on the foot type. Consider once again a hypothetical example.

(42) Iambs: End Rule Right/Left

Language A

Parsing Right to Left, Iamb, End Rule Right

```
(                X)
(. x)   (. x)(. x)
```
$\breve{\sigma}\ \bar{\sigma}\ \breve{\sigma}\ \breve{\sigma}\ \bar{\sigma}\ \breve{\sigma}\ \boldsymbol{\bar{\sigma}}$

Language B

Parsing Right to Left, Iamb, End Rule Left

```
(  X             )
(. x)   (. x)(. x)
```
$\breve{\sigma}\ \boldsymbol{\bar{\sigma}}\ \breve{\sigma}\ \breve{\sigma}\ \bar{\sigma}\ \breve{\sigma}\ \bar{\sigma}$

If each parsing represented a language, then for the given sequences of light and heavy syllables, in Language A the main stress would fall on the word final syllable, while in Language B, main stress would fall on the second syllable of the word. Although these are hypothetical examples, they are by no means exceptional. Consider the examples given in (28). Both Cairene Arabic and Wargamay have a moraic trochee, but the direction of parsing as well as the End Rule are different. As a result, although two and three syllable words look very similar for stress assignment, four syllable words are different. We repeat the crucial examples here.

(43) Moraic trochees in Cairene and Wargamay

Cairene Arabic: Parsing Left-to-Right, End Rule Right

(X)	(X)
(x)	(x .)(x .)
μμ μ	μ μ μ μ
be:tá⟨k⟩	kɑtɑbítu
your (M.SG.) house	she wrote it (M.)

Wargamay: Parsing Right to Left, End Rule Left

(X)	(X)	(X)
(x)	(x .)(x .)	(x .)
μμ μ	μ μ μ μ	μ μμ
mú:bɑ	gíɟawùlu	gɑgárɑ
stone fish	freshwater jewfish	dilly bag

Cairene tends to have main stress towards the end of a word (*katabítu*), while Wargamay has stress at the beginning of the word (*gíɟa-wulu*).

Thus, before we attempt to establish correlations between word rhythm and other phonological constituents, we have to first establish whether we are dealing with iambic/trochaic feet or whether we are referring to merely word edges. Since we are dealing with foot type, direction of parsing, End Rule (plus extrametricality) as parameters for assigning stress, any correlation concerning word rhythm could refer to all of them collectively or any one of them individually.

What types of correlations and implications can we then draw given what we know about metrical patterns? One sort of correlation could be connected with metrical coherence. If languages prefer to stick to a given type of foot for stress, phonological processes as well as morphology, one might think that various types of rules would conspire to achieve a preferred foot. Thus, if the language requires iambs for stress, then vowel lengthening or gemination rules would apply to convert a minimal iamb [$\sigma_\mu\sigma_\mu$] to a canonical one [$\sigma_\mu\sigma_{\mu\mu}$]. Such iambic lengthening examples are frequently mentioned in Hayes (1995). Similarly, as we saw in § 2., epenthesis or deletion processes are often invoked to obtain preferred syllable structures. One could construct a set of strategies that correlate with preferred metrical structures as in (44).

(44) Correlations of preferred metrical structures and repair strategies

	Preferred structures	Strategies
(a)	Languages prefer open syllables	coda deletion, vowel epenthesis
(b)	Languages prefer closed syllables	apocope or syncope; no coda deletion, vowel epenthesis
(c)	Iamb	Iambic lengthening
(d)	Moraic trochee	Trochaic shortening
(e)	Minimal Word	Vowel lengthening, epenthesis

Unfortunately, a constant problem in phonology is that surface output forms can easily be opaque with respect to the metrical structures of the language. Thus, just as iambic lengthening is frequent, deletion of unstressed syllables are equally frequent, reducing a disyllabic iamb [$\sigma_\mu\sigma_{\mu\mu}$] to a monosyllabic one [$\sigma_{\mu\mu}$]. This type of opacity has been addressed repeatedly throughout the history of generative phonology.

In recent research, opacity is elegantly captured in terms of constraint interaction within the framework of Optimality Theory (OT, cf. Prince & Smolensky 1993; McCarthy & Prince 1995; for a recent survey, see Kager 1999). In OT, the explanatory burden is shifted from processes to output candidates. The central claim is that universal grammar is made up of a set of constraints, all of which are available to a given language. The grammar generates a potentially infinite set of output candidates for each input, which are then evaluated based on the constraint system of the language. The candidate which best fits the constraint system is the victor. Languages differ in the way the constraints are ranked. For our purposes, since constraints are violable and can easily conflict, one of the most interesting consequences is that an output form need not conform to all the constraints of the language. Let us consider some of the preferences stated in (44) and examine how they can conflict. A language could have the following preferences translated into constraints:

(45) Possible ranked constraints
a. Last syllable cannot be stressed.
b. Foot is not right-headed; i. e. it is iambic.
c. Main stressed foot aligns with the right edge of a word.

The constraints (a) and (c) are in direct conflict. Constraint (c) says that the head of the foot should coincide with the right edge of the word. Since the foot is an iamb, the last syllable stress seems to be preferred. However, there is a direct conflict with (a) which says right syllables must not be stressed. In (46) we provide two possible candidates given the above ranking.

(46) Possible candidates
i. (. x) (. x) (. x)
σ̆ σ̄ σ̆ σ̄ σ̆ **σ̄**
ii. (. x) (. x)
☞ σ̆ σ̄ σ̆ **σ̄** σ̆ σ̄

Since (43a) is ranked above (43c), the last constraint will lose out and (46 ii) would be the preferred candidate. The output is then opaque to the fact that the head of the foot should preferably line up with the right edge of the word.

What would this mean for the possible typological correlations suggested in (44)? Given that preferences and constraints can be conflicting which predicts that the output may be opaque, we can only state the correlations we have as preferences and not absolute. Obviously, the preferences remain as open questions.

6. Conclusion

In this article, we have established that there are systematic organising principles which construct metrical patterns in natural languages. These organising principles combine various units of prosodic structure like syllables and feet. There is a limited inventory of syllable and foot types for all languages. Stress, which marks relative prominence within metrical constituents, is a result of various independent parameters including the type of foot and the edge of a word and direction of parsing.

Metrical constituents are however, not only relevant for stress but for other phonological and morphological phenomena. We have argued that typologically, languages adhere to metrical coherence within both the phonological and morphological systems of a given language. However, when it comes to drawing correlations between metrical structure and other aspects of phonology and morphology, the typological literature is somewhat uncertain in drawing any conclusions. Part of the reason is that only fixed templatic structures have been taken into account and metrical patterns are not viewed as organising principles of grammatical systems. However, since we do have a well understood set of metrical patterns and are aware of possible processes and constraints, future research will undoubtedly try to lay out meaningful typological implications in this area.

7. References

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97. Tone systems

1. Defining "tone"

Within the phonological realm, few typological issues have generated as much discussion (and controversy) as the issue of tone. It is generally assumed that as many as half of the world's languages are "tonal". While most language families in the world have one or more tonal offsprings, including those in North and South America, Europe, and Oceania, languages with fully developed tone systems are highly concentrated in Subsaharan Africa, Southeast Asia, and Mexico. Beyond these generalities, the typological study of tone systems has at times faltered on the very basic question of what constitutes a "tone" and hence a "tone system". Welmers' (1959, 1973) definition is as good as most: "A tone language is a language in which both pitch phonemes and segmental phonemes enter into the composition of at least some morphemes." Thus, tone is clearly indicated in the case of such pairs as Pawaian [Oceanic] sú 'tooth' and sù 'road' and Mende [Sierra Leone] *pɛ́lɛ́* 'house' and *bɛ̀lɛ̀* 'trousers' (see § 6. for tone-marking conventions). While Pike (1948) had suggested that a tone language has "contrastive, but relative pitch on each syllable", Welmers improves on this definition by recognizing the existence of toneless morphemes, especially grammatical morphemes which take their tone from the surrounding context. If we reinterpret Welmers in modern terms to mean that the pitch phonemes must be presented in "the underlying representations of at least some morphemes", this will allow for the Mende toneless postpositions *-hu* 'in' and *-ma* 'on', which copy their tone from the preceding nominal, e. g. *pɛ́lɛ́-hú, pɛ́lɛ́-má; bɛ̀lɛ̀-hù, bɛ̀lɛ̀-mà*. It is also possible for lexical morphemes to be underlyingly toneless. Hyman (1981) has analyzed tone in Somali as being largely predictable on the