8 Feet and Metrical Stress

René Kager
Utrecht University

8.1   Metrical stress: introduction

8.1.1   What are stress languages?

In stress languages, one or more syllables in each word or phrase is said to be 'more prominent' than others. 'Prominence' is not an intrinsic property of stressed syllables, but a matter of relative strength between 'stronger' and 'weaker' syllables. Most stress languages distinguish only two degrees of stress: stressed and unstressed. Yet a further distinction among stressed syllables into primary and secondary stress is common, while some languages even display a three-way distinction into primary, secondary, and tertiary stress. Here we will use the IPA conventions for stress notation. Primary stress is indicated by a superscript vertical bar before the syllable carrying it, secondary stress by a subscript vertical bar. Consider, for example, the transcription for 'designate': [ˈde.zɪɡ.ˌneɪt].

There is no unique phonetic property corresponding to stress, although it is cross-linguistically highly common for stressed syllables to have higher pitch levels, longer duration, and greater loudness than unstressed syllables. Tones tend to be attracted to stressed syllables (see de Lacy [ch.9], Gussenhoven [ch.11], and Yip [ch.10]). Yet, stress is clearly different from tone in the sense that stress does not assimilate, neither locally between adjacent syllables, nor across longer distances. Cross-linguistically, relations between segmental properties and stress are common. The vowels of stressed syllables are prone to lengthen, while those of unstressed syllables may undergo reduction. Stressed syllables tend to license a larger set of vowels than unstressed syllables.

In 'free stress' languages, word stress is lexically contrastive, resulting in minimal pairs that differ in terms of stress alone (e.g. Russian *bágrit'* 'to spear fish' and *bagrít'* 'to paint crimson'). In 'fixed stress' languages, stress is phonologically predictable, but a word's morphological structure may affect the location of stress. For example, suffixes may attract stress, repel it, or be stress-neutral. Also, prefixes may be included in the word stress domain or fall outside it. This chapter will focus on fixed-stress languages, and mostly ignore contrastive stress and morphological effects.

8.1.2 Cross-linguistic properties of stress

A number of properties of stress languages have been identified, some of which are universal. Among these properties, the following four are well-established.

• *Culminative stress*

'Culminativity' means that there is one and only one maximally prominent peak within a stress domain. It is characteristic of stress languages for grammatical units (stems, words, or phrases) to have minimally one stressed syllable. This stress peak, the most prominent syllable in its grammatical domain, typically serves as the anchoring point for intonational contours (see Gussenhoven [ch.11]). At the word level, culminativity amounts to a stressability requirement, which many languages impose on content words (nouns, verbs, adjectives, or adverbs) while relaxing it for function words (articles, pronouns, prepositions, etc.), which are prosodically dependent on content words (McCarthy & Prince 1986).

• *Demarcative stress*

Stress can have a demarcative function: it signals the beginning and/or end of morphological boundaries. Cross-linguistically, stress tends to be attracted to syllables located near the edges of grammatical units, especially the initial syllable. Since final syllables are exempted from stress in many languages, initial and prefinal syllables are, by far, the most favored locations of stress, followed by stress on the second and final syllable. Examples from Diyari (Austin 1981, Poser 1989) illustrate how stress may serve to highlight morphological structure. All morphemes, stems or suffxes, of length two or more syllables, are stressed on their initial syllable.

(1)   *Diyari: initial stress on all polysyllabic morphemes*
        (a) ˈkana-ni-ˌmata   'man' (loc. iden.)
        (b) ˈkana-ˌwara-ŋgu   'man' (pl. loc.)
        (c) ˈkana-ˌwara-ŋgundu   'man' (pl. abl.)
        (d) ˈjakalka-ˌjirpa-ˌmali-na   'to ask' (ben. recip. part.)

Observe how the minimal binarity requirement on stressability serves to avoid stress on final syllables, as well as on adjacent syllables. This naturally leads us to the next property.

• *Rhythm*

Stress languages show a preference for well-formed rhythmic patterns, where strong and weak syllables are spaced apart at regular intervals. This is manifested by avoidance of adjacent stressed syllables ('clash'), or by avoidance of strings of unstressed syllables ('lapse'). Nevertheless, stress languages vary in degree of rhythmicity. On one end of the spectrum, *bounded* languages occur, with perfectly alternating rhythms, oriented toward the left or right edge of the word. For example, Pintupi (Hansen & Hansen 1969) has stress on the initial syllable and following alternate non-final syllables, while Warao (Osborn 1966) stresses the prefinal syllable and alternate preceding syllables.

(2)   *Pintupi: stress on initial syllable and following alternate nonfinal syllables*
          (a) ˈtʲi.ɭi.ˌri.ŋu.ˌlam.pa.tʲu   'the fire for our benefit flared up'

          (b) ˈju.ma.ˌɻɪŋ.ka.ˌma.ra.ˌtʲa.ˌɻa.ka   'because of mother-in-law'

(3)   *Warao: stress on penultimate syllable and preceding alternate syllables*
          (a) ˌja.pu.ˌru.ki.ˌta.ne.ˈha.se   'verily to climb'
          (b) e.ˌna.ho.ˌro.a.ˌha.ku.ˈta.i   'the one who caused him to eat'

At the opposite end of the rhythmic spectrum we find *unbounded* languages which have one stress per word and no alternating rhythm, allowing long strings of unstressed syllables. Unbounded stress patterns are exemplified in (4)-(5) by Selkup and Western Cheremis. Selkup (Kuznecova et al. 1980, Walker 1997) stresses the rightmost heavy syllable (heavy syllables have long vowels in this language), and otherwise the initial syllable, in forms lacking heavy syllables. Selkup is a so-called 'default-to-opposite-edge' system.

(4)   *Selkup: stress on rightmost heavy syllable, otherwise initial syllable*
          (a) L H L ˈH   qu.moː.qlɪ.ˈlɪː   'your two friends'
          (b) H ˈH L   uː.ˈcoː.mɨt   'we work'
          (c) L L L ˈH   py.na.kɨ.ˈsə ː   'giant!'
          (d) ˈL L L L   ˈqolʲ.cɨm.pa.tɨ   'found'

A 'default-to-same-edge' system occurs in Western Cheremis (Itkonen 1955, Walker 1997), where stress falls on the rightmost nonfinal strong (i.e. full-voweled) syllable and otherwise, in forms lacking nonfinal strong syllables, on the rightmost nonfinal syllable.

(5)   *Western Cheremis: stress on rightmost nonfinal strong syllable, otherwise penult*
          (a) ˈH L H   ˈβaʃ.tə.lam   'I laugh'
          (b) H ˈH L   oʃ.ˈmaʃ.tə   'sand' (iness.)
          (c) L ˈL L   pə.ˈrə.ʃəm   'I went in'
          (d) L ˈL H   ə.ˈməl.tem   'I throw my shade on'

• *Quantity-sensitivity*
Stress prefers to lodge on syllables which have a certain degree of intrinsic prominence. Usually, the relevant property is syllable weight (moraic quantity, see Zec [ch.7]). Long vowels and vocalic diphthongs are always bimoraic; coda consonants are mora-bearing on a language-specific basis, so (C)VC syllables may count as heavy in one language and light in another. Occasionally, stress is attracted by syllables which carry a high tone, or contain a vowel of high sonority (see de Lacy [ch.9]). Stress attraction by heavy syllables was exemplified for unbounded languages by Selkup and Western Cheremis (4-5).

A striking case of a bounded quantity-sensitive pattern is found in Yidiɲ (Dixon 1977). In words containing an even number of syllables which lack long vowels, stress falls on all odd-numbered syllables (6a). When a long vowel occurs in an even-

numbered syllable, stress falls on even-numbered syllables (6b). In words containing an odd number of syllables, the penultimate syllable is lengthened, and stress falls on even-numbered syllables (6c-d).

(6)   *Yidiɲ: mutual dependence of stress and vowel length*
         (a) /gudaga-ni/   ˈgu.da.ˈga.ni   'dog' (gen.)
         (b) /durguː-nu-la/   dur.ˈguː.nu.ˈla   'mopoke owl' (gen./loc.)
         (c) /gudaga/   gu.ˈdaː.ga   'dog' (abs.)
         (d) /guda-gudaga/   gu.ˈda.gu.ˈdaː.ga   'dog' (red.)

This example shows how the presence of stress depends on quantity, as well as how quantity can depend on stress. Yidiɲ lengthens the vowel of a stressed penultimate syllable, increasing its quantity. Another related cross-linguistically common strategy is consonant gemination in stressed syllables. Conversely, vowels in unstressed syllables tend to shorten, reduce, or even delete, thus decreasing their syllable weight, as in English /ætɒm/ 'atom' surfacing as [ˈærəm] and [əˈtʰɒmək] 'atomic'. In sum, quantity-sensitivity amounts to an agreement between quantitative structure (patterns of light and heavy syllables) and metrical structure (groupings into weak and strong syllables).

Although usually a strict division into quantity-sensitive and quantity-insensitive systems is assumed, stress systems actually fall into finer-grained classes, showing various degrees of quantity-sensitivity, with a range of intermediate positions (Kager 1992ab; Alber 1997).

8.2   The formal representation of stress

Our representational basis is *metrical phonology*, a theory whose central assumption is that stress is a relational property, represented by prominence relations between constituents in hierarchical structures (Liberman 1975; Liberman & Prince 1977; Hayes 1980). We use the metrical representation known as *constituentized grid* or *bracketed grid* (Hammond 1984; Halle & Vergnaud 1987; Hayes 1995), which combines the metrical grid with constituency.

8.2.1   The grid

The *metrical grid* forms a hierarchical representation of rhythm (Liberman 1975; Liberman & Prince 1977; Prince 1983; Selkirk 1984), a succession of columns of grid elements of different height. Height of columns represents a syllable's relative prominence. Horizontally, the arrangement of grid elements represents rhythm, from which alternation, stress clash, and stress lapse can be read. As an example, consider the alternating stress pattern of *Apalachicola* [ˌæpəˈlætʃɪˈkoːlə]. Its grid analysis contains six columns, each standing over a syllable. The first, third and fifth columns are taller than the second, fourth and sixth. The fifth column, indicating the grid's culminating peak, is taller than the first and third.

(7) PrWd-level   x
      Foot-level   x   x   x
      Syllable-level   x   x   x   x   x   x
                     ˌæ. pə. ˌæ. tʃɪ. ˈkoː. lə

This particular grid shows a perfect rhythmic alternation, since all strong foot-level beats are separated by a weak syllable-level beat.

The grid, as a representation of rhythm, is essential in the description of word stress patterns. Languages strive towards a rhythmic alternation of strong and weak syllables, avoiding dis-rhythmic situations, known as 'stress clash' and 'lapse'. We define 'clash' as a situation of adjacent strong beats without an intervening weak beat at the next-lower level (Liberman 1975; Liberman & Prince 1977; Prince 1983; Selkirk 1984).

(8) Clash $n+1$ x x
               n x x

'Lapse' is defined as the adjacency of two grid elements at level n, without either having a level n+1 counterpart.

(9) Lapse $n+1$
               n x x

'Rhythmic alternation' is defined as the absence of clash and lapse. Every two grid elements which are adjacent at level n+1 must be separated by precisely one element at level n.

(10) Alternation $n+1$ x   x   x
               n … x x x x x x…

Pure-grid variants of metrical theory, which involve no metrical consituency, were proposed by Prince (1983), Selkirk (1984), and Gordon (2002).

8.2.2 Metrical constituency

Metrical constituency refers to groupings of grid elements at low levels into higher-order elements. Constituency is formally represented by bracketing grid elements by pairs of parentheses (Hammond 1984, Halle & Vergnaud 1987, Halle & Idsardi 1995, Hayes 1995). Each constituent has an obligatory *head*, represented by a grid element at the next-higher level, plus an optional non-head, which has no corresponding mark at the next-higher level. By adding constituency to the grid in (7), we obtain a bracketed representation in (11).

(11)   PrWd-level   x
          Foot-level   (x   x   x   )
          Syllable-level   (x   x) (x   x) (x   x)
                                ˌæ. pə. ˌlæ. tʃɪ. ˈkoː. lə

At the syllable level, pairs of grid elements are bracketed together by parentheses into three *metrical feet:* (æ.pə), (læ.tʃɪ), (koː.lə).   Rhythmically strong syllables, called 'heads', are initial in feet; strong-initial feet are called *trochees*.   Each foot projects its head by an asterisk at the foot level.   Elements at the foot level are similarly bracketed together in a single constituent, whose head is final in English.   This projects a grid element at the Prosodic Word level, the culminative peak of the word.
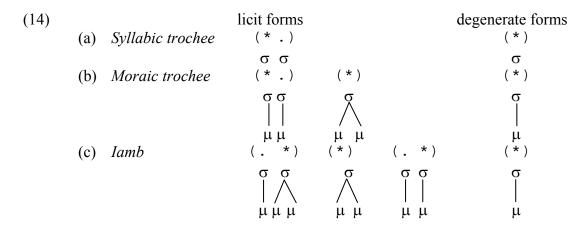
        Hayes (1995) uses a flattened bracketed grid representation, which collapses three layers into two.   Within each constituent, the head is represented by an asterisk, the non-head by a dot.

(12)   .   .   *   )
          (*   . (*   .) (*   .)
          ˌæ. pə. ˌlæ. tʃɪ. ˈkoː. lə

Throughout this chapter, we will use even flatter representations, as exemplified in (12). Dots denote syllable boundaries; parentheses, foot boundaries; and square brackets, PrWd boundaries.   Relative prominence is marked by IPA-style stress marks before syllables:

(13)   [(ˌæ.pə).(ˌlæ.tʃɪ).(ˈkoː.lə)]

These informal representations are notationally equivalent with bracketed grids in (11) and (12).

8.2.3   An inventory of metrical feet

A central hypothesis of metrical theory is that there is a small universal inventory of foot types, and languages can only select types from this inventory.   The particular foot inventory which we focus on (Hayes 1985, 1987, 1995; McCarthy & Prince 1986; Prince 1990) is based on converging evidence from a range of phenomena found in natural languages, including stress patterns, rhythmic lengthening and shortening, word minima, and templates in prosodic morphology.   It contains three basic foot types, two of which are *trochaic* (head-initial), and one *iambic* (head-final).   The quantity-insensitive *syllabic trochee* requires two syllables of indiscriminate weight.   The quantity-sensitive *moraic trochee* has two light syllables, or a single heavy syllable.   Finally, the quantity-sensitive *iamb* has three forms: two light syllables, a single heavy, or a light syllable plus a heavy syllable.

(14)   licit forms   degenerate forms

   (a) *Syllabic trochee*   (* .)   (*)

                        σ σ   σ

   (b) *Moraic trochee*   (* .)   (*)   (*)

                       σ σ   σ   σ
                       μ μ μ μ   μ

   (c) *Iamb*   (. *) (*) (. *) (*)

                σ σ σ σ σ σ
                μ μ μ μ μ μ μ μ

This foot inventory is *asymmetrical* in the sense that it imposes a sharp rhythmic distinction between iambs, whose preferred expansion (light-plus-heavy) is quantitatively uneven, and trochees, which are quantitatively even at the level of the syllable or mora. Another major element of the foot inventory is its distinguishing licit expansions, which meet the requirement of *binarity* at the level of the syllable or the mora, from degenerate expansions, which fall below the binary threshold. Many languages avoid degenerate feet altogether, while other languages allow them only in absolutely peripheral positions or under main stress (Kager 1989, 1993, 1995a; Kiparsky 1991; Hayes 1995, cf. Halle & Idsardi 1995).

      We will use an informal notation for feet, where a syllable of indiscriminate weight is denoted by 'σ', a light syllable by 'L', and a heavy syllable by 'H'. The head of the foot is underlined.

(15)   *licit expansions* *degenerate expansion*

   (a) *Syllabic trochee* (<u>σ</u>σ)   (<u>σ</u>)
   (b) *Moraic trochee* (<u>L</u>L) (<u>H</u>)   (<u>L</u>)
   (c) *Iamb*   (L<u>H</u>) (<u>H</u>) (L<u>L</u>)   (<u>L</u>)

We now turn to a brief discussion of these foot types. For fuller exemplification of stress systems, see typological studies such as Hyman (1977), Hayes (1980, 1995), Halle & Vergnaud (1987), Elenbaas & Kager (1999), Gordon (2002), and the papers in Goedemans, van der Hulst & Visch (1996).

8.2.3.1 Syllabic trochees

The syllabic trochee is exemplified in its most canonical, strictly binary form by languages which lack a syllable weight contrast altogether, such as Pintupi and Warao, where the direction of metrification is rightward and leftward, respectively.

(16) *Pintupi* (Hansen & Hansen 1969): syllabic trochees from left to right
  • Primary stress is initial
  • Secondary stresses fall on every odd-numbered non-final syllable
  (a) (ˈσσ)   ˈpa.ɳa   'earth'
  (b) (ˈσσ) σ   ˈŋu.ɳi.tʲu   'mother'
  (c) (ˈσσ) (ˌσσ)   ˈma.la.ˌwa.na   'through (from) behind'
  (d) (ˈσσ) (ˌσσ) σ   ˈpu.liŋ.ˌka.la.tʲu   'we (sat) on the hill'
  (e) (ˈσσ) (ˌσσ) (ˌσσ)   ˈtʲa.mu.ˌlim.pa.ˌtʲuŋ.ku 'our relation'
  (f) (ˈσσ) (ˌσσ) (ˌσσ) σ   ˈtʲi.ɭi.ˌri.ŋu.ˌlam.pa.tʲu 'the fire for our benefit flared
                                                          up'

(17) *Warao* (Osborn 1966): syllabic trochees from right to left
  • Primary stress is penultimate
  • Secondary stresses fall on even-numbered syllables counting from the right
  (a) (ˈσσ)   ˈti.ra   'woman'
  (b) σ (ˈσσ)   ko.ˈra.nu   'drink it!'
  (c) (ˌσσ) (ˈσσ)   ˌru.hu.ˈna.e   'he sat down'
  (d) σ (ˌσσ) (ˈσσ)   ji.ˌwa.ra.ˈna.e   'he finished it'
  (e) (ˌσσ) (ˌσσ) (ˌσσ) (ˈσσ) ˌja.pu.ˌru.ki.ˌta.ne.ˈha.se 'verily to climb'
  (f) σ (ˌσσ) (ˌσσ) (ˌσσ) (ˈσσ) e.ˌna.ho.ˌro.a.ˌha.ku.ˈta.i 'the one who caused him to
                                                          eat'

The syllabic trochee also serves to analyse languages which possess a syllable weight
contrast, but fully or partially ignore it in stress assignment. Languages of this type are
rare (Kager 1992a,b), a case being Finnish (Hanson & Kiparsky 1996, Elenbaas & Kager
1999). Unstressed heavy syllables occur, so as to to avoid clash, as well as (optionally)
to avoid final stress. As shown by (18b.ii) and (18c.ii), optional alternative metrifications
of (18b.i) and (18c.i), the syllabic trochee allows for a monosyllabic form of a single
heavy syllable.

(18) *Finnish* (Carlson 1978): syllabic trochees with variable quantity-sensitivity
  • Primary stress is initial
  • Secondary stress is variable, partly depending on syllable quantity, where closed
  syllables count as heavy
  (a) (ˈσσ) L   ˈpe.ri.jæ   'inheritor' (nom.)
  (b)   (i) (ˈσσ) H   ˈku.nin.gɑs   'king' (nom.)
          (ii) (ˈσσ) (ˌH)   ˈku.nin.ˌgɑs
  (c)   (i) (ˈσσ) (ˌσσ)   ˈrɑ.vin.ˌto.lɑt   'restaurants' (nom.)
          (ii) (ˈσσ) L (ˌH)   ˈrɑ.vin.to.ˌlɑt

Taking into account similar foot minima in other syllabic trochee languages, Hayes
(1995) proposes to redefine the licit forms of the syllabic trochee as (σ σ) or (H), the so-

called *generalized trochee*. As a result, all three foot types share a definition of the degenerate foot as a single light syllable (L).

8.2.3.2 Moraic trochees

The moraic trochee captures the idea that a single heavy syllable is quantitatively and metrically equivalent to two light syllables (Allen 1973; Halle & Vergnaud 1978; McCarthy 1979; Prince 1983). It is exemplified by the pattern of Cairene Arabic, in particular the stressing of classical Arabic words in this dialect (Mitchell 1960). The foot bracketing is due to Hayes (1995).

(19) *Cairene Arabic* (Mitchell 1960): moraic trochees from left to right
   • Stress falls on the penult or antepenult, whichever is separated by an even number of syllables from the rightmost nonfinal heavy syllable or, if there is no heavy syllable, from the left edge of the word.
   • Secondary stresses are phonetically covert.

   (a) (ˌLL) (ˈLL) L   ʃa.ja.ˈra.tu.hu   'his tree'
   (b) (ˌLL) (ˌLL) (ˈLL)   ʃa.ja.ˌra.tu.ˈhu.ma(a)   'their (dual) tree'

   (c) (ˌH) (ˌLL) (ˈLL)   ˌʔad.ˌwi.ja.ˈtu.hu   'his drugs'
   (d) (ˌH) (ˌLL) (ˈLL) L   ˌʔad.ˌwi.ja.ˈtu.hu.ma(a) 'their (dual) drugs'

The analysis brackets together pairs of moras into feet, going from left to right through the word. Note that heavy syllables cannot be split between feet. Also note that a licit bimoraic trochee cannot consist entirely of a single light syllable – hence the lack of final stress in (19a) and (19d). The theory restricts quantity-sensitive trochees to (LL) quantitatively balanced 'even' trochees, ruling out (HL) 'uneven' trochees.

Hayes (1995) observes that crucial distributional rhythmic evidence for the even trochee comes from rightward metrification, in particular from the parsing of a heavy syllable which is immediately followed by a string of light syllables. Even bimoraic trochees (H), (LL) predict the parsing in (20a), with a clash, while 'uneven' trochees (H), (HL), (LL) predict the rhythmically alternating (20b).

(20) *left-to-right parsing*
   (a) even trochee   →   (ˈH) (ˈLL) (ˈLL)   (ˈʔad).(wi.ja).(ˈtu.hu) 'his drugs'
   (b) uneven trochees →   (ˈHL) (ˈLL) L   *(ˈʔad.wi).(ˈja.tu).hu

This context thus allows differentiation between an 'even' and 'uneven' parsing mode. On the basis of examples such as (37) from Cairene Arabic, Hayes rejects uneven trochees in favour of even trochees. Leftward moraic trochees could not, however, offer direct distributional evidence for the even trochee, since the even trochaic parsing ← (ˈH) L (ˈLL) (ˈLL) is, qua stress distribution, indistinguishable from the uneven parsing ← (ˈHL) (ˈLL) (ˈLL).

Unambiguous examples of right-to-left moraic trochees are rather difficult to obtain. Hayes (1995) analyzes languages such as Maithili in this way.

(21)   *Maithili* (Jha 1958): leftward moraic trochees
    (a) (ˌLL) (ˈH) L   ˌɑ.dʰə.ˈlaː.hə   'bad'
    (b) (ˌLL) (ˈLL)   ˌdʰɑ.nə.ˈhɒ.rə   (no gloss)
    (c) (ˌLL) (ˈH)   ˌpɑ.ʈə.ˈhiː   'thin'
    (d) (ˌH) (ˈH) L   ˌde.ˈkʰaː.rə   'seen'
    (e) (ˈH) (ˌLL)   ˈgaː.ˌbʰi.nə   'pregnant'
    (f) (ˈH) (ˌH)   ˈsaː.ˌʈiː   'woman's garment or cloth'

Hayes' argument for the even trochee in Maithili is indirect, and depends on the placement of primary stress in (21e-f). This involves *foot extrametricality,* a device rendering the final foot ineligible for primary stress placement. In Hayes' analysis, foot extrametricality is triggered by a clash between the final foot's head syllable and the preceding syllable. Moreover, only absolutely final feet can ever be extrametrical, due to the *Peripherality Condition* on extrametricality (Harris 1983). If (HL) were a licit foot, forms such as (21d) would be wrongly predicted to undergo foot extrametricality, resulting in an initial primary stress [(ˈH) (ˌHL)]. Assuming the even parsing [(ˌH) (ˈH) L], the Peripherality Condition correctly blocks extrametricality.

8.2.3.3 Iambs

Iambs are exemplified by Hixkaryana, where foot structure is apparent from the lengthening of vowels in alternating open syllables. Word-final syllables are never lengthened, and can be assumed to remain unfooted. Hixkaryana matches Cairene Arabic in having a rightward metrification.

(22)   *Hixkaryana* (Derbyshire 1979): iambs from left to right
    • Stress falls on heavy syllables and on even-numbered non-final syllables in strings of open syllables. Stressed open syllables are rhythmically lengthened.
    a. /LLL/   → (LˈH) L   to.ˈroː.no   'small bird'
    b. /LLLL/   → (LˈH) L L   a.ˈtʃoː.wo.wo   'wind'
    c. /LLLLL/   → (LˈH) (LˈH) L ne.ˈmoː.ko.ˈtoː.no 'it fell'
    d. /LLHL/   →(LˈH) (ˈH) L   kʰa.ˈnaː.ˈnɨh.no   'I taught you'
    e. /HLLL/   →(ˈH) (LˈH) L   ˈak.ma.ˈtaː.rɨ   'branch'
    f. /HLLLL/   →(ˈH) (LˈH) L L ˈtoh.ku.ˈrʲeː.ho.na 'to Tohkurye'
    g. /HLLLLLLL/→(ˈH)(LˈH)(LˈH)(LˈH)L ˈtoh.ku.ˈrʲeː.ho.ˈnaː.ha.ˈʃaː.ha
                                           'finally to Tohkurye'

The analysis features extrametricality of final syllables, which is highly common in iambic languages.

The iamb is not restricted to languages that have a weight distinction, as Araucanian shows.

(23)   *Araucanian* (Echeverría & Contreras 1965): iambs from left to right
    (a) (σˈσ)   wu.ˈle   'tomorrow'
    (b) (σˈσ) σ   ti.ˈpan.to   'year'
    (c) (σˈσ) (σˌσ)   e.ˈlu.mu.ˌju   'give us'
    (d) (σˈσ) (σˌσ) σ   e.ˈlu.a.ˌe.new   'he will give me'
    (e) (σˈσ) (σˌσ) (σˌσ) ki.ˈmu.fa.ˌlu.wu.ˌlaj 'he pretended not to know'

Hayes (1995) maintains that languages of this type, which have no syllable weight contrast, nor iambic lenghthening, do not counter-exemplify the foot inventory. See Kager (1993) for further discussion.
    Hixkaryana and Araucanian exemplify rightward metrification. The uneven parsing → (LˈL) (LˈL) (LˈH) suits the uneven iamb, although not exclusively, since even iambs would predict the same stress distribution → (LˈL) (LˈL) L (ˈH). To test the prediction about the iamb's uneven shape, a quantity-sensitive case is needed with leftward metrification. Unfortunately, the quantity-sensitive iamb is notoriously rare, the best known case being Tübatulabal.

(24)   *Tübatulabal* (Voegelin 1935): leftward iambs, degenerate feet allowed.
    (a) (LˈL) (LˈL)   wi.ˈtaŋ.ha.ˈtal   'the Tejon Indians'
    (b) (ˈL) (LˈL) (LˈH) (LˈL) ˈwi.taŋ.ˈha.ta.ˈla:.ba.ˈcu
                                     'away from the Tejon Indians'
    (c) (LˈH) (ˈL)   ha.ˈni:.ˈla   'the house' (obj.
    (d) (ˈH) (ˈL) (LˈH)   ˈta:.ˈha.wi.ˈla:p   'in the summer'
    (e) (ˈL) (LˈH) (ˈL) (LˈL) ˈa.na.ˈŋi.ni.nɨ.ˈmut 'he is crying wherever he goes'
                                     (distr.)

The parsing has degenerate feet, just like leftward quantity-insensitive iambic languages, such as Weri. ([ľ] is described as a 'vibrant alveolar' by Boxwell & Boxwell 1966).

(25)   *Weri* (Boxwell & Boxwell 1966): leftward iambs, degenerate feet allowed.
    (a) (LˈL)   ŋɪn.ˈtɪp   'bee'
    (b) (ˌL) (LˈL)   ˌkʊ.ľɪ.ˈpʊ   'hair of arm'
    (c) (LˌL) (LˈL)   ʊ.ˌľʊ.a.ˈmɪt   'mist'
    (d) (ˌL) (LˌL) (LˈL)   ˌa.kʊ.ˌne.te.ˈpaľ   'times'
    (e) (LˌL) (LˌL) (LˈL)   lɪ.ˌlɪ.ŋe.ˌwe.ľɪ.ˈaľ   'two ladders'
    (f) (ˌL) (LˌL) (LˌL) (LˈL) ˌmoľ.mo.ˌľa.i.ˌmen.tɪ.ˈaľ 'two tomatoes'

That is, no languages are attested which have the same stress patterns as Tübatulabal and Weri, except that degenerate feet are disallowed. Here, the initial stress would be

missing in odd-numbered forms, resulting in an initial lapse. The strong correlation between direction of parsing and minimum foot size in right-to-left iambic languages goes unexplained by current foot-based metrical theories. The iambic asymmetry is among the major theoretical issues in metrical phonology.

8.2.3.4 Alternative foot inventories

Alternative foot inventories have been proposed, which depart from asymmetric foot theory in more or less radical ways. Kager (1993), remaining otherwise close to the rhythmic assumptions of asymmetric theory, assumes a strictly binary foot inventory, including a bimoraic iamb. Arguments for the uneven trochees occur in Jacobs (1990, 2000), Rice (1992), van der Hulst & Klamer (1996), and Mellander (2001, 2004). Halle & Vergnaud (1987), Halle (1990), Halle & Kenstowicz (1991), Idsardi (1992), and Halle & Idsardi (1995) assume a symmetrical foot inventory in which grid elements and metrical brackets can be independently manipulated. 'Resolved' feet with branching heads are proposed by Dresher & Lahiri (1991) and Lahiri & Dresher (1999). Some theories allow overlapping foot constituents (Crowhurst & Hewitt 1996, Hyde 2003).

8.3 Metrification in Optimality Theory

This section presents an optimality-theoretic analysis (Prince & Smolensky 1993, McCarthy & Prince 1993a, b) of the preliminary metrical typology developed in §2. The discussion proceeds from binary quantity-insensitive systems to ternary systems, quantity-sensitive systems, and unbounded systems.

8.3.1   Binary quantity-insensitive systems

A binary system is one in which stressed and unstressed syllables alternate by binary intervals, so that all odd-numbered or even-numbered syllables, counting from the left edge or right edge of the word, are stressed. We start our survey with rhythmic patterns which involve light syllables only. Examples come from languages which lack syllable weight distinctions, as well as, occasionally, from languages which have such a distinction. In the typologically most common case, feet must be strictly binary and fall into a single sweep of metrification: such *uni-directional* patterns start from one edge, usually the left, and run to the opposite edge (§3.1.1). The main departure from strict binarity concerns systems in which feet are allowed to be unary under duress (§3.1.2); a departure from uni-directionality concerns systems in which metrification is *bi-directional*, being oriented toward both word edges (§3.1.3).

    We start by observing that foot type (trochee or iamb) will be selected by the relative ranking of two constraints, FtType=Trochee and FtType=Iamb, which determine the side of the head within a foot. Their ranking with respect to other stress constraints is little importance, and for this reason, we leave these constraints out of consideration. Binary rhythm is enforced by two constraints. The first requires all

syllables in a Prosodic Word to be parsed by feet, while the second imposes binarity on feet, excluding feet falling below the threshold (unary, degenerate feet) or above it (unbounded feet).

(26) PARSE-SYL   Syllables are parsed by feet.

(27) FT-BIN   Feet are binary under moraic or syllabic analysis.

While in words composed of an even number of syllables both constraints can be naturally met by an exhaustive parse, these constraints conflict in words that contain an odd number of syllables. In strictly binary patterns, such as Pintupi, unary feet are disallowed by top-ranked FT-BIN. However, this is achieved at the expense of exhaustive parsing, since any word with an odd number of syllables will contain an unfooted syllable, even when parsing is otherwise maximally tight.

(28) Strictly binary feet (Pintupi): FT-BIN » PARSE-SYL

/σ σ σ σ σ/	FT-BIN	PARSE-SYL
(a) (σ σ) (σ σ) (σ)	*!	
☞ (b) (σ σ) (σ σ) σ		*
(c) (σ σ) σ σ σ		* *!*

In alternating patterns which allow degenerate feet, as in candidate (28a), the ranking is reversed, as shown in §3.1.2.
         Although the relative ranking of FT-BIN and PARSE-SYL determines whether feet are binary, the direction of parsing still needs to be settled. The classical OT analysis of directional metrification is based on a pair of foot alignment constraints, ALL-FT-LEFT and ALL-FT-RIGHT (McCarthy & Prince 1993b). For every foot, these constraints calculate the distance, *gradiently* expressed in syllables, between its left (right) edge and the left (right) edge of the word.

(29) ALL-FT-LEFT
      Align (Ft, L, PrWd, L)   "Every foot stands at the left edge of the PrWd."

(30) ALL-FT-RIGHT
      Align (Ft, R, PrWd, R)   "Every foot stands at the right edge of the PrWd."

The total number of violation marks equals the sum of all individual violations by feet. Consequently, when ALL-FT-L or ALL-FT-R is undominated, only one foot, standing at the absolute edge of the word, is allowed. The reverse ranking, with PARSE-SYL dominating ALL-FT-X (where X stands for either 'left' or 'right'), is required for alternating stress systems such as Pintupi and Murinbata.

(31) *Mini-typology: single foot versus multiple feet*
      (a) single foot systems: FT-BIN, ALL-FT-X » PARSE-SYL
      (b) alternating systems: FT-BIN » PARSE-SYL » ALL-FT-X

The analysis of Pintupi, with alternating stresses on non-final odd numbered syllables, shows minimal violation effects of foot alignment, and the resulting left-to-right foot distribution:

(32)   Left-to-right binary feet in Pintupi
        FT-BIN » PARSE-SYL » ALL-FT-L » ALL-FT-R

	/puliŋkalatʲu/	FT-BIN	PARSE-SYL	ALLFTL	ALLFTR
☞	(a) (ˈpu.liŋ).(ˌka.la).tʲu		*	**	*, ***
	(b) (ˈpu.liŋ).ka.(ˌla.tʲu)		*	***!	***
	(c) pu.(ˈliŋ.ka).(ˌla.tʲu)		*	*, **!*	**
	(d) (ˈpu.liŋ).ka.la.tʲu		**!*		***
	(e) (ˈpu.liŋ).(ˌka.la).(ˌtʲu)	*!		**, ****	*, ***

Violation of ALL-FT-L is assessed gradiently: a violation mark is incurred for every syllable occurring between the left edge of a foot and the left edge of the word; for each candidate, violation marks for individual feet are summed. Violations are separated by commas above to make it easier to see which feet are responsible for which violations. The same syllable can be the cause of several violations – one for every foot it appears before. Candidate (32a) incurs a smaller number of marks than its closest competitor (32b), reflecting the minimal difference in the position of the rightmost feet. Since ALL-FT-L pulls all feet towards the left edge of the word, the unparsed syllable ends up in word-final position.

8.3.2 Mixed binary + unary systems

A departure from strict foot binarity resides in systems which allow degenerate feet.

(33)   *Murinbata* (Street & Mollinjin 1981): rightward trochees, degenerate feet allowed.
        a. (ˈσσ)   ˈmam.ŋe   ‘I/he/she said/did to her’
        b. (ˈσσ) (ˌσ)   ˈla.la.ˌma   ‘shoulder’
        c. (ˈσσ) (ˌσσ)   ˈwa.lʊ.ˌmʊ.ma   ‘blue-tongue lizard’
        d. (ˈσσ) (ˌσσ) (ˌσ)   ˈpʰɛ.rɛ.ˌwɛ.rɛ.ˌtʲɛn   ‘season just before the “dry” ’
        e. (ˈσσ) (ˌσσ) (ˌσσ) ˈŋa.ram.ˌka.rʊˈ.ˌŋi.me ‘we (excl.pc.f.) arrived’

By reversing the ranking of (28), exhaustive parsing is achieved at the expense of binarity, making (34a) the winning candidate.

(34)　*Binary plus unary feet (Murinbata)*: Fᴛ-Bɪɴ » Pᴀʀsᴇ-Sʏʟ

/σ σ σ σ σ/	Pᴀʀsᴇ-Sʏʟ	Fᴛ-Bɪɴ
☞　(a) (σ σ) (σ σ) (σ)		*
(b) (σ σ) (σ σ) σ	*!	
(c) (σ σ) σ σ σ	*!**	

Turning to the direction of metrification, we meet with a slight surprise. Both Pintupi and Murinbata have rightward metrification; however, as compared to Pintupi, Murinbata requires the reverse ranking Aʟʟ-Fᴛ-R » Aʟʟ-Fᴛ-L (Green & Kenstowicz 1995).

(35)　*Left-to-right mixed binary-plus-unary feet in Murinbata*
　　　Pᴀʀsᴇ-Sʏʟ » Fᴛ-Bɪɴ » Aʟʟ-Fᴛ-R » Aʟʟ-Fᴛ-L

/pʰɛrɛwɛrɛtʲɛn/	Pᴀʀsᴇ-Sʏʟ	Fᴛ-Bɪɴ	Aʟʟ-Fᴛ-R	Aʟʟ-Fᴛ-L
☞　(a) (ˈpʰɛ.rɛ).(ˌwɛ.rɛ).(ˌtʲɛn)		*	*, ***	**, ****
(b) (ˈpʰɛ.rɛ).(ˌwɛ).(ˌrɛ.tʲɛn)		*	**, ***!	**, ***
(c) (ˈpʰɛ).(ˌrɛ.wɛ).(ˌrɛ.tʲɛn)		*	**, ***!*	*, ***

The leftward trochaic counterpart of Murinbata, with clash between the first two feet (35c), occurs in Biangai (Dubert & Dubert 1973). Iambic systems which allow degenerate feet also occur. The typologically common leftward iambic pattern was already exemplified by Weri (25). The rarer case of rightward iambs, with a clash in odd-numbered forms, is exemplified by Ojibwa.

(35)　*Ojibwa* (Kaye 1973, Piggott 1980): rightward iambs, degenerate feet allowed
　　　(a) (σˈσ) (ˌσ)　　　　　na.ˈga.ˌmo　　　　　'he sings'
　　　(b) (σˈσ) (σˌσ)　　　　ni.ˈbi.mo.ˌse　　　　'I walk'
　　　(c) (σˈσ) (σˌσ) (ˌσ)　ni.ˈna.ga.ˌmo.ˌmin　'we sing'

By varying three factors, namely foot type (trochee versus iamb), directionality (rightward versus leftward), and tolerance of degenerate feet, gradient foot alignment theory, like Hayes' (1995) rule-based framework, predicts eight uni-directional systems, which are tabulated below. The numbers of languages are taken from Gordon's (2002) survey of quantity-insensitive stress languages.

(36)   *Table 1: Overview of uni-directional systems*

	trochees (45 languages)		iambs (9 languages)	
	left-to-right (32 lgs)	right-to-left (13 lgs)	left-to-right (4 lgs)	right-to-left (5 lgs)
strictly binary feet (29 lgs)	('σ σ) (ˌσ σ) ('σ σ) (ˌσ **σ**) **σ** Pintupi (final lapse) 14 languages	(ˌσ σ) ('σσ) σ (ˌσ σ) ('σ σ) Warao (perfect grid) 12 languages	(σ' σ) (σ ˌσ) (σ' σ) (σ ˌσ) σ Araucanian (perfect grid) 3 languages	(σ ˌσ) (σ 'σ) **σ** (**σ** ˌσ) (σ 'σ) *unattested* (initial lapse)
mixed binary + unary feet (25 lgs)	('σ σ) (ˌσ σ) ('σ σ) (ˌσ σ) (ˌσ) Murinbata (perfect grid) 18 languages	(ˌσ σ) ('σσ) (**σ**) (**σ** σ) ('σ σ) Biangai (initial clash) 1 language	(σ 'σ) (σ ˌσ) (σ 'σ) (σ ˌ**σ**) (**σ**) Ojibwa (final clash) 1 language	(σ ˌσ) (σ 'σ) (ˌσ) (σ ˌσ) (σ 'σ) Weri (perfect grid) 5 languages

Considered from a purely rhythmic viewpoint, this set of uni-directional patterns displays interesting properties. Exactly four patterns (38 languages) display perfect rhythmic alternation, allowing neither clash nor lapse. These 'perfect-grid' (PG) patterns are seen in Murinbata, Warao, Araucanian and Weri. The remaining patterns (16 languages) minimally deviate from rhythmic perfection, allowing small deviations in peripheral contexts, in particular a lapse in final position (Pintupi), or a clash between two secondary stresses at the left edge (Biangai) or at the right edge (Ojibwa). One predicted system, with strictly binary iambs going from right to left, remains unattested. This would involve a lapse on the initial syllables of odd-numbered forms, e.g. [σ (σˌσ) (σ'σ)]. Apparently, no languages occur that minimally deviate from the PG by initial lapse. (See §3.5 for further discussion.)

All systems analysed thus far placed the primary stress on the foot at the edge where the iteration started. The position of the primary stress is governed by a pair of antagonistic alignment constraints, ALIGN-HEAD-L and ALIGN-HEAD-L.

(37)   ALIGN-HEAD-L
        Align (PrWd, L, Head/PrWd, L) "The PrWd begins with the primary stress foot."

(38)   ALIGN-HEAD-R
        Align (PrWd, R, Head/PrWd, R) "The PrWd ends with the primary stress foot."

When undominated, ALIGN-HEAD produces primary stress on a foot which is strictly initial or final in PrWd. More interesting are its effects under domination by a foot alignment constraint favouring the opposite edge, when the primary stress comes to lodge on the first or last of a sequence of feet. This places the primary stress on the foot at the opposite edge from where the iteration started. This occurs in languages such as Cairene Arabic, where word stress falls on the rightmost foot of a sequence that is laid down by a left-to-right metrification.

(39)   Word-stress-at-opposite-edge in Cairene Arabic

FT-BIN » PARSE-SYL » ALL-FT-L » ALIGN-HEAD-R

/ʃa.ja.ɾa.tu.hu/	FT-BIN	PARSE-SYL	ALL-FT-L	ALIGN-HEAD-R
☞ (a) (ʃa.ja).(ˈɾa.tu).hu		*	**	*
(b) (ʃa.ja).ɾa.(ˈtu.hu)		*	***!	

An iambic counterpart of Cairene Arabic is Creek.

8.3.3 Bidirectional systems

Thus far we have seen patterns that are laid down by a single sweep of metrification. Another, more complex kind of alternating pattern has a single foot fixed at one edge while remaining feet depart from the opposite edge. For strictly binary trochees, bi-directional patterns occur in Garawa and Piro.

(40) Garawa (Furby 1974): binary trochees; fixed foot at left edge plus alternating feet right to left
 (a) (ˈσσ)   ˈja.mi   'eye'
 (b) (ˈσσ) σ   ˈpun.ja.ɭa   'white'
 (c) (ˈσσ) (ˌσσ)   ˈwa.cim.ˌpa.ŋu   'armpit'
 (d) (ˈσσ) σ (ˌσσ)   ˈka.ma.ɭa.ˌɽi.ɲi   'wrist'
 (e) (ˈσσ) (ˌσσ) (ˌσσ)   ˈja.ka.ˌla.ka.ˌlam.pa   'loose'
 (f) (ˈσσ) σ (ˌσσ) (ˌσσ)   ˈŋan.ki.ɽi.ˌki.rim.ˌpa.ji 'fought with boomerangs'
 (g) (ˈσσ) σ (ˌσσ) (ˌσσ) (ˌσσ) ˈna.ri.ŋin.ˌmu.ku.ˌɲi.na.ˌmi.ra

              'at your own many'

(41) Piro (Matteson 1965): binary trochees; fixed foot at right edge plus alternating feet left to right
 (a) (ˈσσ)   ˈwa.lo   'rabbit'
 (b) σ (ˈσσ)   ru.ˈtxi.txa   'he observes taboo'
 (c) (ˌσσ) (ˈσσ)   ˌtʃi.ja.ˈha.ta   'he cries'
 (d) (ˌσσ) σ (ˈσσ)   ˌsa.lwa.je.ˈhka.kna   'they visit each other'
 (e) (ˌσσ) (ˌσσ) (ˈσσ)   ˌpe.tʃi.ˌtʃhi.ma.ˈtlo.na   'they say they stalk it'
 (f) (ˌσσ) (ˌσσ) σ (ˈσσ)   ˌru.slu.ˌno.ti.ni.ˈtka.na   'their voices already changed'
 (g) (ˌσσ) (ˌσσ) (ˌσσ) (ˈσσ) ˌsa.ple.ˌwhi.ma.ˌmta.na.ˈtka.na

         'they say he went along screaming again'
 (h) (ˌσσ) (ˌσσ) (ˌσσ) σ (ˈσσ)   ˌka.xru.ˌka.khi.ˌma.nma.ta.ˈtka.na

         'they were joking together then, it is said'

The fixed foot requires word-to-foot alignment, requiring that every PrWd begins or ends with a foot, as captured by the constraint pair below:

(42)   ALL-PRWD-LEFT
        Align (PrWd, L, Ft, L)   "Every PrWd begins with a foot."

(43)   ALL-PRWD-RIGHT
        Align (PrWd, R, Ft, R)   "Every PrWd ends in a foot."

The following tableau illustrates the interaction of alignment constraints and PARSE-SYL for Garawa. In the interests of brevity, violations for ALL-FT-R and ALL-FT-L are expressed as numbers; "2, 5" means that one of the feet incurred two violations while another incurred five, to make a total of 7 violations of the constraint.

(44)   *Bidirectional rhythm in Garawa*
        ALIGN-PRWD-L » PARSE-SYL » ALL-FT-R » ALL-FT-L

Input: /'ŋankiɽikirimpaji/	ALIGN-PRWD-L	PARSE-SYL	ALL-FT-R	ALL-FT-L
☞ (a) ('ŋan.ki).ɽi.(ˌki.rim).(ˌpa.ji)		*	2, 5	3, 5
(b) ('ŋan.ki).(ˌɽi.ki).(ˌrim.pa).ji		*	1, 3, 5!	2, 4
(c) ('ŋan.ki).ɽi.ki.rim.(ˌpa.ji)		**!*	5	5
(d) ŋan.('ki.ɽi).(ˌki.rim).(ˌpa.ji)	*!	*	2, 4	1, 3, 5

Bidirectional patterns which allow degenerate feet are rare. One trochaic case is Gosiute Shoshone (Miller 1996; as referred to by Gordon 2002), which has a fixed secondary stress on the final syllable, and alternating stress on odd-numbered syllables. Two iambic cases are Tauya (MacDonald 1990) and Southern Paiute (Sapir 1930).

A factorial typology of systems with strictly binary feet arises when the ranking of foot alignment ALL-FT-X (with X being either Left or Right) is varied with respect to ALIGN-WD-X and PARSE-SYL. (FT-BIN remains undominated throughout the typology).

(45)   *Iterative binary systems*
        (a) single foot systems:
                FT-BIN, ALIGN-PRWD-**X**, ALL-FT-**X** » PARSE-SYL
        (b) unidirectional binary systems:
                FT-BIN, ALIGN-PRWD-**X** » PARSE-SYL » ALL-FT-**X**
        (c) bidirectional binary systems:
                FT-BIN, ALIGN-PRWD-**X** » PARSE-SYL » ALL-FT-**Y**

Depending on the ranking of ALIGN-HEAD-X with respect to ALL-FT-X, systems have primary stress on the same side (as in Pintupi) or on the opposite side (as in Cairene Arabic).

Many languages impose the requirement that the final syllable must be *unstressed*: the PrWd must not end in a stressed syllable. In strictly binary trochaic systems, such as Pintupi, high-ranked FT-BIN already guarantees final non-stressability, but iambic

systems need a special constraint to that effect. A stronger kind of nonfinality is the requirement that final syllables be *unfooted*: the PrWd must not end in a foot. (See again the Hixkaryana pattern in (22)).Both requirements are combined in Prince & Smolensky's version of NONFINALITY:

(46)   NONFINALITY   No prosodic head is final in PrWd.

This is the OT counterpart of 'extrametricality' in rule-based theory. The difference is, of course, that OT constraints are violable. NONFINALITY can give in to avoid violation of higher-ranking constraints, such as those enforcing quantity-sensitivity (see example under unbounded systems below) or minimal word requirements (see §4.2). For further discussion of NONFINALITY, see Hung (1994), Kager (1999), and Hyde (2003).

8.3.4 Ternary systems

Thus far we have seen rhythmic patterns which were based on binary alternation, albeit occasionally obscured by clashes or lapses. Other languages have a 'ternary' style of alternation, where stresses fall on every third syllable, separated by two weak syllables. Ternary rhythmic patterns are exemplified by Cayuvava, where stresses fall on every third syllable, starting at the right edge.

(47)   Cayuvava (Key 1961): antepenultimate syllable, leftward ternary rhythm.
    (a) (ˈσσ)   ˈda.pa   'canoe'
    (b) (ˈσσ)σ   ˈto.mo.ho   'small water container'
    (c) σ(ˈσσ)σ   a.ˈri.po.ro   'he already turned around'
    (d) σσ(ˈσσ)σ   a.ri.ˈpi.ri.to   'already planted'
    (e) (ˌσσ)σ(ˈσσ)σ   ˌa.ri.hi.ˈhi.be.e   'I have already put the top on'
    (f) σ(ˌσσ)σ(ˈσσ)σ   ma.ˌra.ha.ha.ˈe.i.ki   'their blankets'
    (g) σσ(ˌσσ)σ(ˈσσ)σ   i.ki.ˌta.pa.re.ˈre.pe.ha   'the water is clean'
    (h) (ˌσσ)σ(ˌσσ)σ(ˈσσ)σ   ˌtʃa.a.di.ˌro.bo.βu.ˈru.tʃe 'ninety-nine (first digit)'

Kager & Elenbaas (1999) extend the gradient foot alignment analysis to ternary rhythm. Their analysis incorporates the insight from Ishii (1996) that ternarity arises from the interaction of gradient alignment constraints (ALL-FT-X) and an anti-lapse constraint. However, Kager & Elenbaas deviate from Ishii (1996) in employing a grid-based anti-lapse constraint, instead of a foot-based one. Kager & Elenbaas refer to this constraint as *LAPSE, but we will rename it as

(48)   *LONG-LAPSE   A weak beat must be adjacent to a strong beat or the word
                           edge.

This constraint effectively bans sequences of three or more unstressed syllables (Gordon 2002). With ranked above the sequence, ternary rhythms are produced.

(49)   *Ranking for ternarity*
        *LONG-LAPSE » ALL-FT-X » PARSE-SYL

Undominated *LONG-LAPSE restricts the maximal distance between stresses to two. The sub-ranking ALL-FT-X » PARSE-SYL, known from (45a), reduces the number of feet to the bare minimum needed to avoid long lapses. The result is a perfect ternary alternation. An example from Cayuvava shows the activity of *LONG-LAPSE for a six-syllable word. (FT-BIN is assumed to be undominated.)

(50)   *Ternarity in Cayuvava*: words of length 3*n*

/arihihibee/	*LONG-LAPSE	ALL-FT-L	ALL-FT-R	PARSE-SYL
(a) (ˈa.ri).hi.hi.be.e	*!**		****	****
(b) a.ri.hi.(ˈhi.be).e	*!	***	*	****
☞ (c) (ˌa.ri).hi.(ˈhi.be).e		***	*, ****	**
(d) (ˌa.ri).(ˌhi.hi).(ˈbe.e)		**, **!**	**, ****	

A seven syllable word shows how gradient alignment functions not only to reduce the number of feet, see (51e), but also to place the feet, compare (51c-d).

(51)   *Cayuvava*: words of length 3*n*+1

/marahahaeiki/	*LONG-LAPSE	ALL-FT-L	ALL-FT-R	PARSE-SYL
(a) (ˌma.ra).ha.ha.(ˈe.i).ki	*!	4	1, 5	3
(b) (ˌma.ra).ha.(ˈha.e).i.ki	*!	3	2, 5	3
☞ (c) ma.(ˌra.ha).ha.(ˈe.i).ki		1, 4	1, 4	3
(d) ma.ra.(ˌha.ha).e.(ˈi.ki)		2, 5!	3	3
(e) (ˌma.ra).(ˌha.ha).(ˈe.i).ki		2, 4!	1, 3, 5	1

An eight-syllable word shows interaction between two gradient alignment constraints. Two candidates tie (52b-c) on the highest-ranking alignment constraint, so that the lower-rnking constraint steps in.

(52)   *Cayuvava*: words of length 3*n*+2

/ikitaparerepeha/	*LONG-LAPSE	ALL-FT-L	ALL-FT-R	PARSE-SYL
(a) i.(ˌki.ta).pa.(ˈre.re).pe.ha	*!	1, 4	2, 5	4
☞ (b) i.ki.(ˌta.pa).re.(ˈre.pe).ha		2, 5	1, 4	4
(c) (ˌi.ki).(ˌta.pa).re.(ˈre.pe).ha		2, 5	1, 3, 5	2
(d) (ˌi.ki).ta.(ˌpa.re).re.(ˈpe.ha)		3, 6!	3, 6	2
(e) (ˌi.ki).(ˌta.pa).(ˌre.re).(ˈpe.ha)		2, 4, 6!	2, 4, 6	

The interaction of two antagonistic alignment constraints is a typical feature of the OT analysis.

A mini-typology shows skeletal rankings for single foot, binary, and ternary systems.

(53)   *Mini-typology*
          (a) single foot: ALL-FT-X » *LONG-LAPSE , PARSE-SYL
          (b) binary rhythm: *LONG-LAPSE , PARSE-SYL » ALL-FT-X
          (c) ternary rhythm: *LONG-LAPSE » ALL-FT-X » PARSE-SYL

8.3.5   Quantity-sensitive systems

We now turn to stress systems which involve sensitivity to syllable weight. As compared to strings of light syllables only, mixed strings of light and heavy syllables are naturally subject to a larger set of stress-affecting factors, such as stress attraction by heavy syllables, repulsion of stress by light syllables, and stress-induced lengthening and shortening. Consequently, the typology becomes more complicated. We will focus on relatively straightforward patterns of moraic trochees and iambs, examples of which occur in §2.3, while leaving out of consideration more subtle effects of quantity-sensitivity. (See Alber 1997, Kager 1999, Elenbaas 1999.)

Quantity-sensitivity is enforced mainly by the Weight-to-Stress-Principle:

(54)   WEIGHT-TO-STRESS PRINCIPLE (WSP)
          Heavy syllables must be stressed. (If heavy, then stressed.)

This constraint is violated by any heavy syllable that is not prominent, either within or outside a foot. Hence, it expresses the conditional 'if heavy then stressed'. This is illustrated by Tübatulabal (see 24).

(55)   Right-*to-left iambs in Tübatulabal*
          WSP, PARSE-SYL » ALL-FT-L » FT-BIN

/hani:la/	WSP	PARSE-SYL	ALL-FT-L	FT-BIN
☞ (a) (ha.ˈni:).(ˈla)			**	*
(b) (ha.ˈni:).la		*!		
(c) (ˈha).(ni:.ˈla)	*!		*	*

The power of gradient foot alignment is illustrated by the following example, which motivates the ranking ALL-FT-L » FT-BIN:

(56)   *Tübatulabal:* Even string of light syllables between the left edge and a heavy syllable

/witaŋhatala:bacu/	WSP	PARSE-SYL	ALL-FT-L	FT-BIN
☞ (a) ('wi).(taŋ.'ha).(ta.'la:).(ba.'cu)			1, 3, 5	*
(b) (wi.'taŋ).(ha.'ta).('la:).(ba.'cu)			2, 4, 5!	

The reverse conditional, 'if stressed then heavy' is expressed by a gradient constraint, measuring degrees of syllable weight, indicated |x|.

(57)   PEAK PROMINENCE (PK-PROM)
        Peak(x) is more harmonic than Peak(y) if $|x| > |y|$.

This constraint correlates the size of a prominence peak (that is, the height of its grid column) with the quantity of the syllable which carries it. More concretely, it requires the tallest peak to lodge on the heaviest syllable. We will see applications below in unbounded stress systems.

8.3.6 Unbounded systems

Unbounded stress systems broadly fall into two classes: default-to-same-edge systems, exemplified by Western Cheremis in (5), and default-to-opposite-edge systems, as exemplified by Selkup in (4). The standard analysis (e.g. Prince & Smolensky 1993; Zoll 1996; Walker 1997; Bakovic 1998) is based on the interaction of alignment constraints, quantity-sensitivity constraints, and nonfinality constraints.
        The analysis of *default to same* systems involves the core ranking PK-PROM » ALIGN-HEAD.

(58)   Default-to-same: PK-PROM » ALIGN-HEAD
        (a)

/H L H/	PK-PROM	ALIGN-HEAD-R
☞ (a) H L 'H		σ
(b) H 'L H	*!	σσ
(c) 'H L H		σσ!σ

(b)

/L L L/	PK-PROM	ALIGN-HEAD-R
☞ (a) L L 'L	*	
(b) L 'L L	*	σ!
(c) 'L L L	*	σ!σ

In default-to-same systems, two types of nonfinality effects occur (Prince & Smolensky 1993; Walker 1997). First, nonfinality may hold for all final syllables, regardless of syllable weight. Such 'quantity-insensitive nonfinality' is found in Western Cheremis.

(59) QI nonfinality (Western Cheremis): NONFINALITY » PK-PROM » ALIGN-HEAD-R
(a)

	HHL /oʃmaʃtə/	NONFINALITY	PK-PROM	ALIGN-HEAD-R
	(a) oʃ.maʃ.'tə	*!	*	
☞	(b) oʃ.'maʃ.tə			σ
	(c) 'oʃ.maʃ.tə			σσ!

(b)

	LLH /əməltem/	NONFINALITY	PK-PROM	ALIGN-HEAD-R
	(a) ə.məl.'tem	*!		
☞	(b) ə.'məl.tem		*	σ
	(c) 'ə.məl.tem		*	σσ!

(c)

	HLH /βaʃtəlam/	NONFINALITY	PK-PROM	ALIGN-HEAD-R
	(a) βaʃ.tə.'lam	*!		
	(b) βaʃ.'tə.lam		*!	σ
☞	(c) 'βaʃ.tə.lam			σσ

(d)

	LLL /pərəʃəm/	NONFINALITY	PK-PROM	ALIGN-HEAD-R
	(a) pə.rə.'ʃəm	*!	*	
☞	(b) pə.'rə.ʃəm		*	σ
	(c) 'pə.rə.ʃəm		*	σσ!

Quantity-sensitive nonfinality is found in Sindhi (Khubchandani 1969, Walker 1997). If a word has only one heavy syllable (CVV, CVC), stress falls on it (60a, b). If a word has more than one heavy syllable, stress falls on the rightmost nonfinal heavy syllable (60c, d, e). In words composed of light syllables only, the penult is stressed (60f, g).

(60) *Sindhi: Quantity-sensitive non-finality*
(a) LH   ɖʰə.'goː   'ox'
(b) HLL   'səh.kə.ɳʊ   'to gasp'
(c) HLH   'oː.cɪ.toː   'sudden'
(d) HLLH   'moː.kɪ.lɪ.ɳoː 'to be sent'
(e) HHH   kʰoː.'liːn.da   'they will open' (trans.)
(f) LL   'bʰɪ.tɪ   'wall'
(g) LLL   ʊ.'tʰə.lə   'inundation'

This is accounted for by re-ranking PK-PROM and NONFINALITY, so that stress falls on a final syllable if it is the only heavy syllable in the word.

(61)   QS nonfinality (Sindhi): PK-PROM » NONFINALITY » ALIGN-HEAD-R
        (a)

	LH /dʰəgoː/	PK-PROM	NONFINALITY	ALIGN-HEAD-R
☞	(a) dʰə.ˈgoː		*	
	(b) ˈdʰə.goː	*!		σ

        (b)

	HLH /oːcɪtoː/	PK-PROM	NONFINALITY	ALIGN-HEAD-R
	(a) oː.cɪ.ˈtoː		*!	
	(b) oː.ˈcɪ.toː	*!		σ
☞	(c) ˈoː.cɪ.toː			σσ

        (c)

	LLL /ʊtʰələ/	PK-PROM	NONFINALITY	ALIGN-HEAD-R
	(a) ʊ.tʰə.ˈlə	*	*!	
☞	(b) ʊ.ˈtʰə.lə	*		σ
	(c) ˈʊ.tʰə.lə	*		σσ!

The analysis of default-to-opposite systems requires an additional constraint, which draws stress to the opposite edge of the word if there are no heavy syllables. This is a licensing constraint (Zoll 1996, Walker 1997), which bans stressed light syllables except in initial position.

(62)   ALIGN (L, PrWd, L)   A stressed light syllable must be PrWd-initial.

This constraint is illustrated below for Selkup (Walker 1997):

(63)   Default-to-same. Selkup: rightmost heavy, else initial
        ALIGN (L, PRWD, L) » ALIGN-HEAD-R
        (a)

		LHLH /qumoːqlɪlɪː/	ALIGN (L, PRWD, L)	ALIGN-HEAD-R
☞	(a)	qu.moː.qlɪ.ˈlɪː		
	(b)	qu.moː.ˈqlɪ.lɪː	*!	σ
	(c)	qu.ˈmoː.qlɪ.lɪː		σ!σ
	(d)	ˈqu.moː.qlɪ.lɪː		σ!σσ

(b)

	LLLH /pynakɨsəː/	ALIGN (L, PRWD, L)	ALIGN-HEAD-R
☞	(a) py.na.kɨ.ˈsəː		
	(b) py.na.ˈkɨ.səː	*!	σ
	(c) py.ˈna.kɨ.səː	*!	σσ
	(d) ˈpy.na.kɨ.səː		σ!σσ

(c)

	LLLL /qolʲcɨmpatɨ/	ALIGN (L, PRWD, L)	ALIGN-HEAD-R
	(a) qolʲ.cɨm.pa.ˈtɨ	*!	
	(b) qolʲ.cɨm.ˈpa.tɨ	*!	σ
	(c) qolʲ.ˈcɨm.pa.tɨ	*!	σσ
☞	(d) ˈqolʲ.cɨm.pa.tɨ		σσσ

The typology of default-to-opposite systems includes nonfinality effects, which will not be discussed.

Thus far, we have seen some virtues of rhythmic alignment constraints. However, the next section will expose certain problems for gradient alignment theory.

8.3.7 *Revising classical alignment theory*

Stress typology contains a well-known gap, already identified above: in strictly binary iambic systems, parsing is uniformly leftward (Kager 1993, 2001; Hayes 1995; McCarthy & Prince 1993a; van de Vijver 1998; Alber 2001; Hyde 2003). The classical theory, which assumes foot type (trochee or iamb) to be dissociated from foot distribution, predicts four strictly binary uni-directional patterns. Yet, only three patterns are attested, see (36). This asymmetry cannot be attributed to a universal prohibition against leftward iambic parsing, since leftward iambs do in fact occur in languages such as Weri and Tübatulabal, which allow unary feet by the ranking PARSE-SYL » FT-BIN. In sum, an unexplained interdependence holds between foot type, foot binarity, and directionality of parsing. Kager (2001) observes that the missing pattern suffers from a rhythmic defect: it contains a *word-initial lapse*. Cross-linguistically, initial lapses are sharply disfavored, in contrast to final lapses, which widely occur in stress languages, for example in Pintupi. The lapse asymmetry is known from other rhythmic domains, in particular musical rhythm, where double upbeats are avoided (Lerdahl & Jackendoff 1983).

Kager proposes that parsing is controlled by local rhythmic configurations, rather than by gradient alignment. He introduces a set of *rhythmic licensing* constraints, which ban lapses everywhere except in one specific context. An example is in (70).

(70) LAPSE-AT-END   Lapse must be adjacent to the right edge.

This constraint assigns one violation mark for each pair of unstressed syllables, except the final one. In a trochaic language like Pintupi, this attracts the unparsed syllable to the word end, giving the illusion of a directional, rightward parsing. ALL-FT-X is now

dispensed with, while word-to-foot alignment is no longer gradient, and becomes categorical.

The factorial typology of the revised constraint set does not contain the iambic initial lapse pattern as this is 'harmonically bounded' (Samek-Lodovici & Prince 1999). If the violations of a candidate C_1 form a proper subset of those of another candidate C_2, then C_2 cannot be generated under any ranking of constraints in the set. The iambic initial lapse pattern (78d) is harmonically bounded by any iambic candidate which has the same number of feet, satisfies right-edge alignment, but in addition satisfies left-edge alignment.

(71)   *Harmonic bounding of the initial lapse pattern*

/σ σ σ σ σ σ σ/	*Lapse	Lapse-to-End	Align-Wd-L	Align-Wd-R
☞ (a) (σ́σ)σ̱(σ̱σ́)(σ́σ)	*	*		
(b) σ̱(σ̱σ́)(σ́σ)(σ́σ)	*	*	*!	

Although the initial lapse pattern (71b) is eliminated, the resulting iambic typology still contains a gap, since (71a), a bidirectional pattern, is also unattested. Nevertheless, the typology is more restrictive than the standard typology, which generates both gaps (71a-b).

In rhythmic licensing theory, the following ranking produces the pattern of Pintupi:

(72)   *Lapse-based analysis of Pintupi*
Ft-Bin, Align-Wd-L, Lapse-at-End » Parse-Syl, *Lapse

/puliŋkalatʲu/	Ft-Bin	Align-Wd-L	Lapse-at-End	Parse-Syl	*Lapse
☞ (a) (ˈpu.liŋ).(ˌka.la).tʲu				*	*
(b) (ˈpu.liŋ).ka.(ˌla.tʲu)			*!	*	*
(c) (ˈpu.liŋ).ka.la.tʲu			*!*	***	***
(d) pu.(ˈliŋ.ka).(ˌla.tʲu)		*!		*	
(e) (ˈpu.liŋ).(ˌka.la).(ˌtʲu)	*!				

Kager (2001) observes a second gap, which is more subtle, but equally puzzling as the iambic gap. In bidirectional systems, directional footing always starts from the edge opposite from the edge where the fixed foot lodges. This is shown for strictly binary trochaic systems below.

(44)   *Table 2: Overview of bidirectional trochaic systems with strictly binary feet*

	fixed foot right plus left-to-right	fixed foot left plus right-to-left
primary stress on fixed foot	(ˌσσ)(ˌσσ)(ˈσσ) (ˌσσ)(ˌσσ̱)σ̱(ˈσσ) Piro	(ˈσσ)(ˌσσ)(ˌσσ) (ˈσσ̱)σ̱(ˌσσ)(ˌσσ) Garawa
secondary stress on fixed foot	(ˌσσ)(ˌσσ)(ˈσσ) (ˌσσ)(ˌσσ)σ(ˈσσ) unattested	(ˌσσ)(ˌσσ)(ˈσσ) (ˌσσ̱)σ̱(ˌσσ)(ˈσσ) unattested

In the standard analysis, the edge specification of the fixed foot is independent of directionality of parsing, hence all four strictly binary bidirectional trochaic systems are predicted. These gaps cannot be attributed to a resulting mismatch between directionality of parsing and the End Rule (Hammond 1984, van der Hulst 1984), because languages exist that exhibit mismatches, such as Cairene Arabic. Nor can the gap be attributed to a mismatch between the edge of the fixed foot and the End Rule, since such mismatches occur in languages which allow unary feet, such as Southern Paiute. Why there should be interdependence between the edge of the fixed foot and the edge of the End Rule? Again, the restriction is stateable in terms of rhythmic targets: the lapse occurs immediately before the stress peak, as in Piro, or immediately after the peak, as in Garawa. This motivates another rhythmic licensing constraint.

(73)   LAPSE-AT-PEAK   Lapse must be adjacent to the peak.

As an example of a bidirectional system, consider the analysis of Garawa.

(74)   *Lapse-based analysis of Garawa*
ALIGN-WD-R, ALIGN-WD-L, LAPSE-AT-PEAK » PARSE-SYL, LAPSE-AT-END

/ˈŋankiɾikirimpaji/	ALIGN-WD-R	ALIGN-WD-L	LAPSE-AT-PEAK	PARSE-SYL	LAPSE-AT-END
☞ (a) (ˈŋan.ki).ɾi.(ˌki.rim).(ˌpa.ji)				*	*
(b) (ˈŋan.ki).(ˌɾi.ki).rim.(ˌpa.ji)			*!	*	*
(c) (ˈŋan.ki).(ˌɾi.ki).(ˌrim.pa).ji	*!		*	*	

The unattested trochaic pattern (74b) is harmonically bounded by (74a). Consequences of the rhythmic licensing theory for quantity-sensitive systems need further investigation. (See Alber 2001, to appear for some issues to be addressed.)

McCarthy (2003) generalizes Kager's proposal to abandon gradient foot alignment so that all constraints become categorical. He re-evaluates cases that apparently require gradient alignment (unbounded stress and foot extrametricality), and finds no compelling evidence for gradient algnment. This conclusion is re-inforced by work in computational phonology suggesting that formally, gradient constraint evaluation is a rather questionable device (Riggle 2004; Biró 2004; Heinz, Kobele & Riggle 2005). These modifications of classical foot alignment theory show an increased reliance on the

grid, while remaining within representational assumptions of bracketed-grid theory. Taking the rhythmic perspective further, Gordon (2002) develops a grid-only typology for quantity-insensitive stress, while Hyde (2003) questions one-to-one mapping between constituents and the grid. Probably, we will see a reassessment of the balance between rhythm and constituency in metrical phonology in the years ahead.

8.4   Feet in phonological domains and prosodic morphology

This section identifies evidence for metrical feet apart from stress patterns. Feet can be domains for phonological processes, minimal word conditions, and templates in morphologically-sensitive processes.   Of course, feet within a language should be consistent – if the stress pattern requires iambs, then word minimality requirements should also demand iambs, and so on; this consistency of foot form within the same language is called the *metrical cohesion hypothesis* (Prince 1980; Hayes 1982, 1995; McCarthy & Prince 1986; Dresher & Lahiri 1991; cf. Gordon 1999). Among the non-stress phenomena to be discussed here are feet as domains for phonological processes, minimal word conditions, and templates in prosodic morphology.

8.4.1 Feet as phonological domains

Vowel lengthening and shortening are often sensitive to foot structure. For example, many languages display a process of rhythmic lengthening of vowels in alternating even-numbered syllables, often excluding the final syllable of the word. See Hixkaryana (22) for illustration.   Rightward iambs, respecting nonfinality, account for the rhythmic distribution of vowel lengthening and the exclusion of final syllables, while supplying a rationale of vowel lengthening as filling the foot template (LH) to its maximal size. Similarly, vowels in unstressed syllables undergo vowel reduction (licensing inside or outside the foot: Dutch (Kager 1989), Russian (Crosswhite 1999).
      Evidence for the even moraic trochee comes from various sources. Uneven sequences /HL/, when forced into a bimoraic foot, undergo trochaic shortening /HL/ → (LL) in Latin (Mester 1991) and Fijian (Dixon 1988, Prince 1990, Hayes 1995). Another strategy to attain bimoraic trochees is vowel shortening, as in Tongan (Churchward 1953, Mester 1991, Prince & Smolensky 1993, Hayes 1995).

(80)   *Two reactions to a sequence* ...HL#
      (a) Fijian: trochaic shortening
           /siːβi/   [(ˈsi.βi)]   'to exceed'
     cf.   /siːβi-ta/ [(ˌsiː).(ˈβi.ta)] 'to exceed' (trans.)
      (b) Tongan: vowel breaking
           /huː/   [(ˈhuː)]   'to go in'
     cf.   /huː-fi/   [hu.(ˈu.fi)]   'to open officially'

Both languages avoid a heavy plus light sequence at the end of a word, and strive toward a situation in which a bimoraic trochee is right-aligned in the word.

Although the asymmetrical foot inventory accounts for an impressive set of quantitative changes in natural languages, it also meets with a number of challenges. For example, some trochaic languages display a process of stressed vowel lengthening, which typically affects the main stress, but sometimes alternating syllables (Mellander 2001, 2004). Iambic lengthening might thus be construed as a special case of the general process of stressed vowel lengthening, which is specifically enhanced in iambic feet due to lapse avoidance within the foot (Kager 1993), or domain-final lengthening (Revithiadiou & van de Vijver 1997; van de Vijver 1998). Another kind of evidence which challenges the uneven iamb comes from segmental processes which suggest metrification into bimoraic even iambs (LL), (H). The key example is fortition in Chugach Yupik (Leer 1985, Kager 1993). All foot-initial consonants have a fortis realization.

(81)   *Chugach Yupik fortition governed by even iambs*
(a) /LLLL/   (a.ˈku).(**ta**.ˈmek)   *akutaq* (a food) (abl.sg.)
(b) /LLLLLL/   (**m**a.ˈŋar).su.(**q**u.ˈta).(**q**u.ˈni) 'if he (refl.) is going to hunt porpoise'
(c) /HLH/   (ˈɑn).tʃi.(**q**uɑ)   'I'll go out'
(d) /HLLH/   (ˈ**n**ɑː).(**m**ɑ.ˈtʃi).(ˈ**q**uɑ)   'I will suffice'

Note especially how the parsing of (81c) deviates from the prediction of the uneven theory, [(H)(LH)].

Other phonological sources of evidence for metrical feet involve stress shifts after the deletion of stressed vowels (Halle & Kenstowicz 1991; Hayes 1995), foot boundaries creating opaque domains to further metrification (Free Element Condition; Steriade 1988; Halle & Kenstowicz 1991), and tonal phenomena (see Yip [ch.10]).

8.4.2 Minimal words

Another type of evidence for the metrical foot derives from minimal word effects. Many languages require stems to have a fixed minimum size, such as two syllables or a single heavy syllable, matching a binary *foot*. The requirement that a stem minimally equal a foot derives from the prosodic hierarchy, which requires every element at level *n* (here, the PrWd) to dominate at least one element at level *n-1* (here, a foot). The following constraint captures the relation between a morphological category (Stem) and a prosodic category (PrWd).

(82)   STEM=PRWD   'For every stem, there is a PrWd and the stem and PrWd's boundaries coincide'

If FT-BIN is high-ranked, as can be verified in the stress system, it follows that the minimal word must be binary as well.

Strong evidence for word minima comes from languages which actively reinforce it by avoiding subminimal words. This may happen by means of epenthesis or lengthening in subminimal words, or by means of the blocking of otherwise general processes of deletion, where deletion would produce a subminimal (monosyllabic or monomoraic) word. Augmentation is illustrated by examples from Iraqi Arabic (epenthesis, 83a) and Levantine Arabic (lengthening, 83b):

(83)   *Epenthesis driven by the minimal word*
        (a) Mohawk (Michelson 1981): /k-tat-s/ → [iktats] 'I offer'
        (b) Levantine Arabic (Broselow 1995): /sʔal/ → [sʔaal] 'ask' (m. sg.)
        (c) Hixkaryana (Derbyshire 1979): /kʷaja/ → [kʷaːja] 'red and green macaw'

The Hixkaryana example in (83c) shows an interaction of subminimal lengthening with nonfinality. Since the final syllable cannot be footed, words of two light syllables undergo subminimal lengthening of the first syllable.

        The blocking of apocope (i.e. deletion of word-final vowels) to avoid a subminimal word is illustrated by Lardil and Estonian.

(84)   *Apocope blocked if it would result in a sub-minimal word*
        (a) Lardil (Wilkinson 1988)
            /majara/   → [majar]   'rainbow
            /kela/   → [kela]   'beach'   *[kel]
        (b) Estonian (Prince 1980)
            /tænɑvɑ/ → [tænɑv]   'street' (nom.sg.)
            /kɑnɑ/   → [kɑnɑ]   'chicken' (nom.sg.)   *[kɑn]
            /koi/   → [koi]   'clothes-moth' (nom.sg.) *[ko]

The examples above give evidence for disyllabic or bimoraic feet. Evidence for the uneven iamb (LH) from minimal word requirements is difficult to obtain, since both (H) and (LL) are licit feet.

8.4.3 Morphological templates

A final source of evidence for metrical feet comes from templates in prosodic morphology, as found in reduplication, truncation and classical template-based morphology. McCarthy & Prince (1986) stated the general relation between morphological templates and prosodic categories (including foot) in their *Prosodic Morphology Hypothesis:* "templates are defined in terms of authentic units of prosody (mora, syllable, foot, PrWd, etc.)". They hypothesized that the set of feet required for templatic morphology matches the foot typology for stress systems: syllabic trochee, moraic trochee, and iamb.

   Examples of foot-sized templates, including reduplications and truncations, are below, for all three foot types:

(85)   *Disyllabic templates* [σσ]
       (a) Yidiɲ (Dixon 1977): reduplicant is [σσ]

stem	*reduplicated stem*
mulari	mula-mulari
kintalpa	kintal-kintalpa

       (b) French (Tranel 1993): hypocoristic is [σσ]

name	*hypocoristic*
dominik	domi
ameli	meli

(86)   *Bimoraic templates* [LL], [H]
       (a) Japanese (Poser 1984): hypocoristic is [LL], [H]

name	*hypocoristic*
midori	mido-tjaɴ, miː-tjaɴ
wasaburoː	wasa-tjaɴ, waː-tjaɴ

       (b) Manam (Lichtenberk 1983): reduplicant is [LL], [H]

stem	*reduplicated stem*
salaga	salaga-laga
malaboŋ	malabom-boŋ

(87)   *Iambic templates* [H], [LH]
       (a) Arabic (McCarthy & Prince 1993a): broken plural is [LH]

singular	*broken plural*
nafs	nufuːs
ʔasad	ʔusuːd

       (b) Central Alaskan Yup'ik (Woodbury 1985): proximal vocative is [H], [LH]

full noun	*proximal vocative*
qətunɣak	qət ~ qətun
aŋukaɣnaq	aŋ ~ aŋuk

The template was translated into an alignment constraint schema by McCarthy & Prince (1993b):

(88)   *Constraint schema for classical templates*
        MCAT=PCAT
            where Mcat ≡ Morphological Category ≡ Prefix, Suffix, RED, Root, Stem, LexWd, etc.
            and Pcat ≡ Prosodic Category ≡ Mora, Syllable (type), Foot (type), PrWd (type), etc.

McCarthy & Prince (1994, 1995, 1999) proposed to eliminate the classical template by interactions of violable constraints. The *Generalized Prosodic Morphology Hypothesis* says that templatic conditions are the reflection of canonical prosodic restrictions on the morphological category that an item (such as a reduplicative morpheme) belongs to, categories like stem and affix. Templatic specification is minimal, consisting only of a statement to the effect that the reduplicant equals an 'affix' or a 'stem', while the reduplicant's shape characteristics are derived from interactions of prosodic well-formedness constraints and constraints on reduplicative identity. This approach can be illustrated with an example from Diyari (Austin 1981, Poser 1989).

(89)   *Diyari reduplication* (copies initial foot, minus coda of second syllable)
        (a) wiḻa   wiḻa-wiḻa   'woman'
        (b) kuḻkuŋa   kuḻku-kuḻkuŋa   'to jump'
        (c) tʲilparku   tʲilpa-tʲilparku   'bird species'

Properties of the Diyari stress system underlie the exact disyllabicity of the reduplicant. The language has initial primary stress, and a secondary stress falls on the third syllable of a four-syllable stem.

(90)   (a) ˈwiḻa   'woman'
        (b) ˈtʲilparku   'bird species'
        (c) ˈwiḻaˌpina   'old woman'

This trochaic stress pattern is due to the constraint ranking in (91).

(91)   FT-BIN » PARSE-SYL » ALL-FT-LEFT

The disyllabic reduplicant also matches the minimal prosodic word of Dirayi: all stems are minimally disyllabic. The claim that the reduplicant is a PrWd is confirmed by stress. The examples below show that a primary stress falls on both the base and the reduplicant:

(92)   (a) ˈwiḻa   cf. ˈwiḻa-ˈwiḻa   'woman'
        (b) ˈtʲilparku   cf. ˈtʲilpa-ˈtʲilparku   'bird species'
        (c) ˈwiḻaˌpina   cf. ˈwiḻa-ˈwiḻaˌpina   'old woman'

Since each primary stress heads one PrWd, the reduplicant must equal a PrWd itself.

According to Generalized Template Theory (McCarthy & Prince 1995), the shape invariance of reduplicants emerges from interactions of markedness constraints and constraints of reduplicative identity. Universally reduplicants tend to have unmarked prosodic structures, a property which follows from an increased role of prosodic markedness constraints in shaping reduplicants. Template-specific prosodic requirements are thus reduced to a bare minimum, such as 'RED=AFFIX' or 'RED=STEM'.

All that needs to be stated specifically for the Diyari reduplicant is that this equals a stem:

(93)   RED=STEM   The reduplicant is a stem.

The reduplicant's stem status implies PrWd status, due to undominated STEM=PRWD. Crucially, PrWd must be minimally a foot in size, due to the prosodic hierarchy, in which every PrWd is headed by a foot. This single-foot minimum translates as a *disyllabic minimum*, due to undominated FT-BIN, and the language's overall quantity-insensitivity. What is more, the exact limitation of the reduplicant to a single disyllabic foot follows from metrical constraints that are high-ranked in Diyari.

(94)   a.   The reduplicant's foot is disyllabic (by FT-BIN)
       b.   The reduplicant's syllables are exhaustively parsed (by PARSE-SYL)
       c.   The reduplicant's foot is left-aligned, hence single-footed (by ALL-FT-L)

This is an *emergence of the unmarked* in the Diyari reduplicant. Finally, note that strict disyllabicity is imposed on reduplicants, but not on non-reduplicant stems. This is accounted for segment faithfulness on the stem domain (IO-correspondence) takes precedence over metrical well-formedness, which takes takes precedence over reduplicative identity (BR-correspondence). This analysis of Diyari shows that 'unmarked' prosody in the reduplicant's shape can be attributed to universal markedness constraints. It takes *violable* constraints to reach this conclusion: the same universal markedness constraints which govern the reduplicant are violated in non-reduplicative forms of the language.

8.5   Conclusion

The metrical theory of word stress captures a range of cross-linguistic generalizations about rhythmic patterns by postulating a mixed rhythmic-constituentized representation, the 'bracketed grid', a small alphabet of metrical feet, together with a small set of metrical constraints. The asymmetrical inventory of feet receives additional support from foot-based segmental processes, as well as from word minima and templates in prosodic morphology. The standard optimality-theoretic treatment of stress patterns, based on a gradient interpretation of alignment, which closely mimicked the predictions of earlier rule-based models of directional metrification, has been criticized for giving grid-based rhythmic patterns too small a role in predicting gaps in typologies. Future developments

in metrical theory are likely to redress the balance between constituent-based and grid-based principles of explanation.

For further reading

McCarthy, John, & Alan Prince (1993b). Generalized Alignment. In G.E. Booij and J. van Marle, eds. Yearbook of Morphology 1993. Dordrecht, Kluwer. 79-153. (Excerpted in McCarthy 2004).

Hayes, Bruce (1995). *Metrical Stress Theory: Principles and Case Studies*. Chicago: University of Chicago Press.

Elenbaas, Nine and René Kager. 1999. Ternary rhythm and the *LAPSE constraint. *Phonology* **16**. 273-330. (Also excerpted in McCarthy 2004.)

Gordon, Matthew (2002). A factorial typology of quantity-insensitive stress. *Natural Language and Linguistic Theory* **20**. 491-552.

McCarthy, John (2003). OT constraints are categorical. *Phonology* **20**. 75-138.

References

Alber, Birgit (1997). Quantity sensitivity as the result of constraint interaction. In G.E. Booij & J. van de Weijer (eds.) *Phonology in progress: progress in phonology. HIL phonology papers III*. The Hague: Holland Academic Graphics. 1-45.

Alber, Birgit (2001). Right-alignment as avoidance of stress lapse and stress clash. Handout of talk at WCCFL XX, USC - February 24th 2001. ROA-515.

Alber, Birgit (2002). Clash, Lapse and Directionality. Manuscript, Università di Trento. ROA-568. To appear in NLLT.

Allen, W. Sidney (1973). *Accent and rhythm*, Cambridge: Cambridge University Press.

Austin, Peter (1981). *A grammar of Diyari, South Australia*.

Bakovic, Eric (1998). Unbounded Stress and Factorial Typology. *In RuLing Papers I: Workilng Papers from Rutgers University*, ed. Ron Artstein and Madeline Holler. 15-28. New Brunswick, NJ. (As excerpted by McCarthy 2004.)

Biró 2004.

Boxwell, Helen, and Maurice Boxwell (1966). Weri phonemes. In S.A. Wurm (ed.) *Papers in New Guinea linguistics*, vol. 5 (Linguistic Circle of Canberra Publications, Series A, No. 7). Canberra: The Australian National University. 77-93.

Broselow, Ellen (1995).

Carlson, Lauri (1978).

Crosswhite, Katherine (1999). *Vowel reduction in Optimality Theory*. PhD dissertation, UCLA.

Crowhurst, Megan & Mark Hewitt (1995). Prosodic overlay and headless feet in Yidiɲ, *Phonology* **12**. 39-84.

Derbyshire, D.C. (1979). *Hixkaryana*. [Lingua Descriptive Studies 1.] Amsterdam: North-Holland.

Dixon, R.M.W. (1977). *A grammar of Yidiɲ*. Cambridge: Cambridge University Press.

Dixon, R.M.W. (1988). *A grammar of Boumaa Fijian*. Chicago: University of Chicago Press.

Dresher, Elan & Aditi Lahiri (1991). The Germanic foot: metrical coherence in Old English. *Linguistic Inquiry* **22**. 251-286.

Dubert & Dubert (1973).

Echeverria & Contreras (1965).

Elenbaas, Nine (1999). *A unified account of binary and ternary stress*. PhD dissertation, Utrecht University. Available from ROA 397.

Elenbaas, Nine and René Kager. 1999. Ternary rhythm and the *LAPSE constraint. *Phonology* **16**. 273-330. (Also excerpted in McCarthy 2004.)

Furby, Christine (1974). Garawa phonology. *Pacific Linguistics*, Series A, Australian National University.

Goedemans, Rob, Harry van der Hulst & Ellis Visch (1996). Stress patterns of the world. HIL Publications II. Holland Academic Graphics. The Hague.

Gordon, Matthew (1999) . *Syllable weight: phonetics, phonology, and typology*. PhD dissertation, UCLA.

Gordon, Matthew (2002). A factorial typology of quantity-insensitive stress. *Natural Language and Linguistic Theory* **20**. 491-552.

Green & Kenstowicz (1996). The lapse constraint. Unpublished ms, MIT. Available from ROA 101.

Halle, Morris (1990). Respecting metrical structure. *NLLT* **8**. 149-176.

Halle, Morris & William Idsardi (1995). General properties of stress and metrical structure. In J. Goldsmith (ed.), *A handbook of phonological theory*. Oxford: Basil Blackwell. 403-443.

Halle, Morris & Michael Kenstowicz (1991).

Halle, Morris & Jean-Roger Vergnaud (1987). *An essay on stress*. Cambridge, Mass.: MIT Press.

Hammond, Michael (1984). *Constraining metrical theory: a modular theory of rhythm and destressing*. PhD dissertation, University of California, Los Angeles. [Published 1988, New York: Garland Press.]

Hansen, Kenneth C. & L.E. Hansen (1969). Pintupi phonology, *Oceanic Linguistics* **8**. 153-170.

Hanson, Kristin & Paul Kiparsky (1996). A parametric theory of poetic meter. *Language* **72**: 287-334.

Heinz, Kobele & Riggle (2005).

Harris, James (1983). *Syllable structure and stress in Spanish: a nonlinear analysis* [*Linguistic Inquiry Monograph* 8]. Cambridge: MIT Press.

Hayes, Bruce (1980). *A metrical theory of stress rules*. PhD dissertation, MIT. [Published 1985, New York: Garland Press.]

Hayes, Bruce (1982). Metrical structure as the organizing principle of Yidin[y] phonology. In H. van der Hulst & N. Smith (eds.), *The structure of phonological representations. Part I*. Dordrecht: Foris. pp. 97-110.

Hayes, Bruce (1985). Iambic and trochaic rhythm in stress rules. In M. Niepokuj, M. VanClay, V. Nikiforidou & D. Jeder (eds.) *Proceedings of the Berkeley Linguistics Society* **11**. 429-446.

Hayes, Bruce (1987). A revised parametric metrical theory. In J. McDonough & B. Plunket (eds.) *Proceedings of the North East Linguistic Society* **17**. 274-289.

Hayes, Bruce (1995). *Metrical stress theory: principles and case studies*. Chicago: University of Chicago Press.

Hulst, Harry van der (1984). *Syllable structure and stress in Dutch*. Dordrecht: Foris.

Hulst, Harry van der, & Marian Klamer (1996). The uneven trochee and the structure of Kambera roots. In M. Nespor & N. Smith (eds) *Dam Phonology*. The Hague: Holland Academic Graphics.

Hung, Henrietta (1994). *The rhythmic and prosodic organization of edge constituents*. PhD dissertation, Brandeis University, Waltham, Mass. [ROA-24, http://ruccs.rutgers.edu/roa.html]

Hyde, Brett. (2003). A restrictive theory of metrical stress. *Phonology* **13**. 313-359.

Hyman, Larry. 1977. On the nature of linguistic stress. In L. Hyman (ed.), *Studies in Stress and accent* (Southern California Occasional Papers in Linguistics 4), 37-82. Los Angeles: University of Southern California.

Idsardi, William J. (1992). *The computation of prosody*. PhD dissertation, MIT.

Ishii, Toru (1996), An optimality theoretic approach to ternary stress systems. In B. Agbayani and N. Harada (eds.), *Proceedings of the South Western Optimality Theory Workshop (SWOT II). UCI Working Papers in Linguistics, Volume 2*.

Itkonen (1955).

Jacobs, Haike (1990). On markedness and bounded stress systems. *The Linguistic Review* **7**: 81-119.

Jacobs, Haike (2000). The revenge of the uneven trochee: Latin main stress, metrical constituency, stress-related phenomena and OT. In Lahiri, Aditi (ed.) *Analogy, Levelling, Markedness*, Mouton de Gruyter, Berlin, New York: 333-352.

Jha (1958)

Kager, René (1989). *A metrical theory of stress and destressing in English and Dutch*. Dordrecht: Foris.

Kager, René (1992a). Shapes of the generalized trochee. In J. Mead (ed.) *Proceedings of the West Coast Conference on Formal Linguistics* **11**. 298-311.

Kager, René (1992b). Are there any truly quantity-insensitive systems? In L.A. Buszard-Welcher, L. Lee & W. Weigel (eds.) *Proceedings of the Berkeley Linguistics Society* **18**. 123-132.

Kager, René (1993). Alternatives to the iambic-trochaic law. *Natural Language and Linguistic Theory* **11**. 381-432.

Kager, René (1995). Consequences of catalexis. In Hulst, H. van der & J. van de Weijer (eds.), *Leiden in last: HIL phonology papers*. Holland Institute of Generative Linguistics.

Kager, René (1999). *Optimality Theory*. Cambridge University Press.

Kager, René (2001). Rhythmic directionality by positional licensing. Handout of presentation given at HILP-5, University of Potsdam, 11 January, 2001. (Originally presented at the International Conference on Stress and Rhythm, Hyderabad, 11-15 December 2000.) ROA-514.

Kaye, Jonathan (1973). Odawa stress and related phenomena. In G.L. Piggott & J. Kaye (eds.), *Odawa Language Project: second report*. University of Toronto: Centre for Linguistic Studies. pp. 42-50.

Key, Harold (1961). Phonotactics of Cayuvava. *IJAL* **27**. 143-150.

Khubchandani (1969).

Kiparsky, Paul (1991). Catalexis. Unpublished ms. Stanford University and Wissenschaftskolleg zu Berlin.

Kuznecova et al. (1980)

Lahiri, Aditi & B. Elan Dresher (1999). Open Syllable Lengthening in West Germanic. *Language* **75**.678-719.

Leer, Jeff (1985). Prosody in Alutiiq. In Krauss, M. (ed.), *Yupik Eskimo prosodic systems: descriptive and comparative studies*. Alaska Native Language Center, Fairbanks.

Lerdahl, Fred & Ray Jackendoff (1983). *A generative theory of tonal music*. Cambridge: MIT Press.

Liberman, Mark (1975). *The intonational system of English*. PhD dissertation, MIT.

Liberman, Mark & Alan Prince (1977). On stress and linguistic rhythm. *Linguistic Inquiry* **8**. 249-336.

Lichtenberk, Frantisek (1983).

MacDonald (1990).

Matteson, Esther (1965). *The Piro (Arawakan) language*. [University of California Publications in Linguistics 22.] Berkeley & Los Angeles: University of California Press.

McCarthy, John (1979). *Formal problems in Semitic phonology and morphology*. PhD dissertation, MIT. [Published 1985, New York: Garland Press.]

McCarthy, John (2003). OT constraints are categorical. *Phonology* **20**. 75-138.

McCarthy (ed., 2004)

McCarthy, John & Alan Prince (1986). Prosodic morphology. Ms, University of Massachusetts, Amherst and Brandeis University. [Annotated version 1996, issued as Technical report #32, Rutgers Center for Cognitive Science.]

McCarthy, John & Alan Prince (1993a). Prosodic morphology I: constraint interaction and satisfaction. Ms, University of Massachusetts, Amherst and Rutgers University.

McCarthy, John, & Alan Prince (1993b). Generalized Alignment. In G.E. Booij and J. van Marle, eds. Yearbook of Morphology 1993. Dordrecht, Kluwer. 79-153. (Excerpted in McCarthy 2004).

McCarthy, John, & Alan Prince. 1994. The emergence of the unmarked: Optimality in Prosodic Morphology. In Proceedings of the North East Linguistic Society 24, ed. Mercè Gonzàlez, 333-79. (Excerpted in McCarthy 2004).

McCarthy, John & Alan Prince (1995). Faithfulness and reduplicative identity. In J. Beckman, L. Walsh Dickey & S. Urbanczyk (eds.). 249-384.

McCarthy, John & Alan Prince (1999). Faithfulness and identity in prosodic morphology. In R. Kager, H. van der Hulst & W. Zonneveld (eds.), *The prosody-morphology interface*. Cambridge: Cambridge University Press.

Mellander, Evan (2001). Quantitative processes in trochaic systems. In K. Megerdoomian and L.A. Bar-el (eds.), *Proceedings of the Twentieth West Coast Conference on Formal Linguistics (WCCFL)*. 414-427. Somerville, MA: Cascadilla Press.

Mellander, Evan (2004). (<u>HL</u>)-creating processes in a theory of foot structure. *The Linguistic Review* 20(2-4): 243-280. Mester, R. Armin (1990). Patterns of truncation. *Linguistic Inquiry* **21**. 478-485.

Mester, R. Armin (1991). Some remarks on Tongan stress. Ms, University of California, Santa Cruz.

Michelson (1981).

Miller (1996).

Mitchell (1960).

Osborn, Henry (1966). Warao I: phonology and morphophonemics. *International Journal of American Linguistics* **32**. 108-123.

Piggott, Glyne (1980). *Aspects of Odawa morphophonemics*. New York: Garland Publishing.

Poser, William (1984).

Poser, William (1989). The metrical foot in Diyari. *Phonology* **6**. 117-148.

Prince, Alan (1980). A metrical theory for Estonian quantity. *Linguistic Inquiry* **11**. 511-562.

Prince, Alan (1983). Relating to the grid. *Linguistic Inquiry* **14**. 19-100.

Prince, Alan (1990). Quantitative consequences of rhythmic organization. In M. Ziolkowski, M. Noske & K. Deaton (eds.) *Papers from the Chicago Linguistic Society* **26:2**. 355-398.

Prince, Alan & Paul Smolensky (1993). Optimality Theory: constraint interaction in generative grammar. Ms, Rutgers University, New Brunswick & University of Colorado, Boulder. [Technical report #2, Rutgers University Center for Cognitive Science. To appear, Cambridge, Mass.: MIT Press.]

Revithiadou, Anthi & Ruben van de Vijver (1997). Durational contrasts and the Iambic/Trochaic Law. In V. Samiian (ed.), *Proceedings of WECOL*. Department of Linguistics, California State University, Fresno, CA, pp. 229-242

Rice, Curtis (1992). *Binarity and ternarity in metrical theory: parametric extensions*. PhD dissertation, University of Texas, Austin.

Riggle (2004)

Samek-Lodovici, Vieri & Alan Prince (1999).

Sapir, Edward (1930).   Southern Paiute, a Shoshonean language. *Proceedings of the American Academy of Arts and Sciences* **65:1-3**.

Selkirk, Elisabeth O.   (1984).   *Phonology and syntax: the relation between sound and structure*. Cambridge, Mass.: MIT Press.

Street, Chester S. and Gregory P. Mollinjin (1981). The phonology of Murinbata. In B. Waters (ed.), *Australian phonologies: Collected papers*, 183-244. Work Papers of the Summer Institute of Linguistics, Australian Aborigines Branch A, 5. Darwin: Summer Institute of Linguistics.

Steriade, Donca (1988). Greek accent: a case for preserving structure. *Linguistic Inquiry* **19**: 271-314.

Tranel, Bernard (1993). French liaison and elision revisited: A unified account within Optimality Theory. ROA 15.

Vijver, Ruben van de (1998).   *The iambic issue: iambs as a result of constraint interaction.*   [HIL dissertations 37.] Leiden: Holland Institute of Generative Linguistics.

Voegelin (1935).

Walker, Rachel (1997).   *Mongolian stress, licensing, and factorial Typology*. Ms., University of California at Santa Cruz. [Downloadable from Rutgers Optimality Archive, http://roa.rutgers.edu, ROA-172.]

Wilkinson, Karina (1988). Prosodic structure and Lardil phonology. *Linguistic Inquiry* 19:2, 325-334.

Woodbury (1985).

Zoll, Cheryl (1996). *Parsing below the segment in a constraint based framework*. PhD dissertation, UC Berkeley. [ROA-143, http://ruccs.rutgers.edu/roa.html]