FOOTFORM Decomposed: Using primitive constraints in OT*

Jason Eisner, University of Pennsylvania

1. Goals of the work

Hayes (1995) makes an extensive study of metrical stress systems, within a unifying typological framework. The typology is based on earlier work by Hayes (1985) and McCarthy & Prince (1986); it is marked by several striking asymmetries between iambic and trochaic languages. Hayes makes the following claims:

- That all iambic languages are sensitive to syllable weight (quantity); in particular, they stress every heavy syllable (Prince's (1990) "weight-to-stress" principle). By contrast, some trochaic languages are quantity-insensitive.

- That any iambic language may mix feet of the form $(\smile\acute{\smile})$, $(\smile\acute{-})$, and $(\acute{-})$ within the same word. Trochaic languages divide into two separate types according to the foot shapes they allow, and *neither* type is a mirror image of the iambic case.

(1)	**Iamb**	$(\smile\acute{-})$ or, if necessary, $(\smile\acute{\smile})$ or $(\acute{-})$
	Moraic Trochee	$(\acute{\smile}\smile)$ or $(\acute{-})$
	Syllabic Trochee	$(\acute{\sigma}\sigma)$, where each σ may be either $-$ or $\smile$

- That iambic languages often lengthen stressed syllables in branching feet (**iambic lengthening**, or **IL**), turning $(\smile\acute{\smile})$ into $(\smile\acute{-})$. Trochaic languages do not.

- That iambic languages always assign feet from left to right (**LR**): there are no clear cases of RL iambs. Trochaic languages may assign feet in either direction.

- Additional fact: For trochaic languages, LR footing is in complementary distribution with final-syllable extrametricality. (This is a striking gap in the languages that Hayes catalogs, though Hayes does not explicitly note it, and to my knowledge it has not been previously noticed; see §18.)

The present paper shows how to reproduce the asymmetric Hayesian typology in a natural way within Optimality Theory. All the above facts are derived naturally from internal linguistic principles. I propose that iambic languages fail

*This material is based upon work supported under a National Science Foundation Graduate Fellowship. Many thanks to Gene Buckley, Laura Downing, and Susan Garrett for their valuable comments.

Appears in Benjamin Bruening (ed.), Proceedings of SCIL VIII.
MIT Working Papers in Linguistics, vol. 31, Cambridge, MA, 1997.

to mirror trochaic ones because of well-known universal facts: that both (a) realize syllable weight via extra material at the *right* edge of a syllable[1] and (b) almost invariably realize extrametricality at the *right* edge of the word (Hayes 1995, 57–58). In all other respects, the constraint systems used for iambic and trochaic languages are perfect mirror images of each other. (That is, each metrical constraint has both an iambic version and a mirror-image trochaic version; a single systemic parameter causes a language to use either all the iambic (right-strong) versions or else all the trochaic (left-strong) versions of these constraints.[2])

The paper was undertaken as a challenging case study in **primitive Optimality Theory** (Eisner 1997a, 1997b) or **OTP**, sketched in §3, in which only extremely simple and local constraints are available. The question was, could stress systems really be analyzed in this restricted framework? In particular, could one dispense with such non-local apparatus as FtBin (Prince & Smolensky 1993), FootForm (Prince 1990, Cohn & McCarthy 1994), and especially Align (McCarthy & Prince 1993)? And would the resulting systems be *ad hoc* and unrelated, or would they help to *explain* the cross-linguistic facts for metrical (and non-metrical) stress, such as those listed above?

2. Foot form and the space of possible constraints

Optimality Theory, or **OT** (Prince & Smolensky 1993), is surely capable of stating the asymmetric facts reviewed in §1. The question is whether it can capture them in a linguistically interesting way. At least three strategies are available within OT, the third being the OTP approach pursued in this paper.

Strategy A. *Allow (an incomplete set of) parametric constraints like those in (2). Each constraint from the* StressSystem *family attempts to specify the stress system completely: whichever one is ranked highest wins at the expense of the others.*

(2) a. StressSystem(Syllabic Trochee, RL, Right): The surface form is stressed as if footed with syllabic trochees, assigned iteratively from right to left, with right extrametricality, in the manner of Hayes (1995), Chapter 3.

b. StressSystem(Iamb, LR, None): The surface form is stressed as if footed with iambs, assigned iteratively from left to right, with no extra-

[1] Kager (1993) likewise uses the asymmetry of syllable structure to explain why iambs tend to be unbalanced, (⌣—́), while trochees tend to be balanced. Kager makes some crucial assumptions that are deeply at odds with those of the present account—that stress lapse is detectable only within a foot and not between feet; that stress may fall in mid-foot, `(.x.)`; that stress is attracted to the *first* mora of a heavy syllable, rather than the second, as suggested here; and finally, that footing is both directional and seriously iterative, with an ability to "look backward" but not "forward" in order to avoid clash. The last point means that Kager's account, while ingenious, cannot be easily expressed within Optimality Theory.

[2] Equivalently, one could say that there is only one version of the constraint, which refers only to "strong" and "weak" edges. In iambic languages "strong" means "right," and in trochaic languages it means "left."

metricality, in the manner of Hayes (1995), Chapter 3.

c. . . .

This is the most direct solution imaginable: a literal restatement of Hayes's parametric system. Such a move is superficial, but it is not obviously wrong or unprincipled. It even achieves a prominent goal of OT research (Prince & Smolensky 1993): any reranking of the constraints in (2) yields an attested language.

Yet of course strategy A is hard to take seriously. First, why is it being stated in OT? The central intuition of OT is that phonology emerges through the *interaction* of *violable* constraints. Here, however, all the work is being done within a single, never-violated constraint such as (2a).

Second, one wonders: what *else* can be stated in OT if this can? The constraints in (2) require several pages of a book chapter to specify. May a constraint really incorporate any algorithm, no matter how complex or stipulative? If we say yes, then OT can easily be used to describe unattested and presumably unlearnable languages. This would reduce OT to the status of an *unfalsifiable descriptive notation*.

On this view, OT would make no claims of its own about universal grammar (UG), except for the weak claim that constraint ranking really *is* a mechanism available to UG—alongside many more traditional mechanisms, such as iterative footing and ordered rewrite rules, which may be expressed internal to a constraint as in (2). Any other UG principles would have to be expressed independently of the OT mechanism.

Such a theory should not be rejected out of hand. However, it would mean that OT is not the radical new paradigm that one might expect, but rather a technical extension comparable to the introduction of cyclic rules (Mascaró 1976). Much linguistic work would have to remain focused on what happens *within* constraints, rather than *between* constraints. In particular, what is the precise statement of each complex constraint? How does such a statement of content vary diachronically or typologically, other than by being reranked? Which details of the statement are universal, and how is a language learner to induce the others?

Strategy B. *Employ constraints such as* FootForm$(\cdots)$ *to select foot shape,* Align$(\cdots)$ *for directionality of footing, and* NonFinality *for extrametricality.*[3]

This type of account is standard in OT (for example, Cohn & McCarthy 1994). Yet on closer inspection, it is not too different from strategy A. It merely breaks Hayes's account into its superficial elements: the three constraints of strategy B (FootForm, Align, and NonFinality) correspond respectively to the three parameters of strategy A (foot shape, directionality, and extrametricality). The account still does not crucially rely on one constraint's forcing another to be

[3]Introduced respectively by Prince (1990), McCarthy & Prince (1993), and Prince & Smolensky (1993).

violated.[4]

Worse, while Strategy B has neater, smaller constraints than Strategy A, perhaps we should still be concerned about what they say. A central issue of pre-OT phonology was how to limit the behavior of rules. Yet the constraints above are not limited in any obvious way.

For example, it has frequently been asserted that UG allows only *local* rules. Traditional accounts of metrical stress (Prince 1983, Halle & Vergnaud 1987, Kager 1993, Hayes 1995) respect locality: they employ an iterative footing mechanism that has access to only a small, moving window of context. Yet the directionality constraint ALIGN-L(F, *PrWd*) is decidedly *non*-local. It must measure the distance from each foot all the way to the edge of the word, and sum the distances, and then minimize that sum.

FOOTFORM constraints are not as non-local as ALIGN constraints, but they are more complex. Hayes (1995) argues from data such as (3) that while $(\smile\acute{\smile})$ and $(\acute{-})$ are acceptable iambs, $(\smile\acute{-})$ is preferred. This leads to the constraint in (4) (see also Prince (1990)). But (4) is graded, conjunctive, and not entirely local in that it must simultaneously evaluate conditions spanning the width of an entire foot. Even the weaker constraint in (5), from Prince & Smolensky (1993), might be suspect by pre-OT standards: as formulated, it must "count to 2," rather than just counting to "not one."

(3) Non-final iambic lengthening in Choctaw: underlying *či-habina-či-li* $\smile\acute{\smile}\smile\acute{\smile}\smile\acute{\smile}$ surfaces as *čiháːbináːčili* $(\smile\acute{-})(\smile\acute{-})(\smile\acute{\smile})$
(4) FOOTFORM(Iamb): $(\smile\acute{-}) \succ \{(\smile\acute{\smile}), (\acute{-})\} \succ$ other shapes.
(5) FTBIN: Feet are binary at some level of analysis (μ or σ).

Under strategy B, in short, a measure of simplicity and explanatory adequacy is lost in the move to OT, without changing the paradigm or explaining the paradigmatic gaps.

Strategy C. *Use only simple, local constraints, of a sort that is well-motivated by phonological phenomena* <u>*other than stress*</u>. *Show that an appropriate choice of such constraints will predict Hayes's typology.*

This strategy is the most radical—and the most attractive, provided that it can be made to work. It is part of a broader program that attempts to nail down the details of the OT formalism: to identify, once and for all, *what sort of constraints human grammars may use* and *what sort of representations they constrain*. Such a program would make OT into a complete, falsifiable formal framework in which to write and process grammars.

§3 proposes such a formal framework. Only certain simple and extremely

[4] With one minor exception. Just as Hayes says a language may *mark* certain syllables as *unfootable*, NONFINALITY says it may *constrain* certain syllables to be *unfooted*. A language chooses extrametricality by ranking this constraint so highly that it can override PARSE-σ and ALIGN.

local constraints are allowed: one cannot directly express STRESSSYSTEM, FOOTFORM, or ALIGN, just as one rightly cannot express "unnatural" constraints like PALINDROMIC. §4–§10 show how this framework can account successfully for even the metrical (and non-metrical) stress data.

Strategy C has an added bonus: it presses the linguist to construct explanatory grammars. Unlike Strategies A and B, the metrical account proposed here does not merely stipulate Hayes's typological asymmetries via complex constraints like FOOTFORM(Iamb), as these are disallowed. Rather, it shows the metrical asymmetries to emerge from the onset-coda asymmetry and the preference for right-edge extrametricality.

3. OTP: Optimality Theory with Primitive constraints

To limit the families of constraints that OT grammars can enforce, we ought to ask: What constraints have proved useful to date? Informal study of the OT literature suggests that the same mechanisms are used over and over. This section sketches OTP (Eisner 1997a, 1997b), a restricted version of OT that schematizes these recurring mechanisms into two families of "primitive" constraints.

The **implication** constraint $\alpha \rightarrow \beta$ *requires* each α to overlap temporally with some β. It assesses 1 violation for each α that does not.

The corresponding **clash** constraint, denoted $\alpha \perp \beta$, *prohibits* each α from overlapping with any β. It assesses 1 violation for each instance of overlap.

Thus, $\alpha \rightarrow \beta$ says α's attract β's, while $\alpha \perp \beta$ says α's repel β's. These primitive constraints are highly *local*, in that each violation results from some instantaneous phonological configuration. The constraints state only what must be present or absent *at the moment an α appears*. But what is α? In each primitive constraint, α specifies either the interior or an edge of a type of constituent—which may in turn be prosodic ($[\sigma]$), articulatory (privative $[voi]$), morphological ($[Root]$), or domain ([*high-domain*]). The same is true of β.

While a full discussion is beyond the scope of this paper, very many constraints can be directly expressed this way, as (6)–(7) illustrate. The uniform notation highlights that the constraints have the same form.[5]

(6)	a.	$nas \rightarrow voi$	every nasal feature must overlap [cf. link to] a voicing feature	
	b.	${}_{\sigma}[\rightarrow {}_{C}[$	every σ must be coinitial with a C	[cf. ONSET: ALIGN-L(σ,C)]
	c.	$]_{nas} \rightarrow]_{\sigma}$	nasality ends on a syllable boundary	[must spread over coda]
	d.	${}_{F}[\rightarrow {}_{\sigma}[$	every foot must start on a syllable boundary	[cf. ALIGN-L(F, σ)
	e.	$F \rightarrow {}_{\sigma}[$	every foot must cross over a syllable boundary	[cf. MIN-2 (Green 1995)]
	f.	$\sigma \rightarrow F$	every syllable must overlap a foot	[cf. part of PARSE-σ]
	g.	$\underline{voi} \rightarrow voi$	all underlying voicing ($\underline{voi}$) projects surf. voicing (voi)	[cf. MAX-voi]
	h.	$voi \rightarrow \underline{voi}$	all surface voicing must be licensed by underlying voicing	[cf. DEP-voi]

[5]The English descriptions in (6)–(7) have less in common. A single constraint can admit of several English descriptions: (6a) could have been written as "nas projects voi," "voi licenses nas," "every nas aligns to a voi," or "voicelessness is incompatible with nasality."

(7)	a.	$low \perp$ ATR	low vowels may not bear ATR	[cf. CLASH: *[low, ATR]]
	b.	$cor \perp lab$	no segments are both coronal and labial	[cf. *COMPLEXARTIC]
	c.	$]_{PrWd} \perp]_F$	the end of a word is unfooted (extrametrical)	[cf. NONFINALITY]
	d.	$\sigma \perp {}_F[$	each syllable must stay within a single foot	
	e.	$F \perp {}_M[$	feet may not cross morpheme boundaries	[cf. TAUTOMORPHEMIC-FOOT (Crowhurst, ROA-65)]
	f.	$]_{voi} \perp {}_C[$	progressive voicing: voi may not end just before C, but may spread	
	g.	$voi \perp]_{\underline{voi}}$	no progr. voicing (surface voi can't spread over underlying $]_{\underline{voi}}$ edge)	
	h.	$]_{\mathrm{HD}} \perp {}_{\mathrm{HD}}[$	high-tone domains may not be adjacent	[cf. OCP]
	i.	HD $\perp$ LD	high-tone domains may not overlap low-tone domains	
	j.	HD $\perp \sigma$	high-tone domains are short as possible	[trick to "measure" distance]

Some comparisons may be helpful. The clash family $\alpha \perp \beta$ is more commonly notated *[α, β], but this notation is unsuitable here because α and β may themselves be written with brackets. The implication family $\alpha \rightarrow \beta$ resembles the Generalized Alignment or GA family (McCarthy & Prince 1993) in that its constraints have the form $\forall\alpha.\exists\beta.\cdots$ and can align edges. However, it is both *more* powerful than GA, in that α and β can be constituent interiors, not just edges, and *less* powerful than GA, in that it does not measure the distance from α to β.

What are the representations? The primitive constraints control the relative timing of articulatory gestures, and other autosegmental constituents such as syllables, along a continuous **constituent timeline**. Accordingly, the phonological forms are represented as in Optimal Domains Theory (Cole & Kisseberth 1994). All constituents have width; each type of constituent is on a separate autosegmental tier. Constituents on the same tier may not overlap.

(8) a.

```
voi[          ]voi
nas[          ]nas
  C[       C][C          ]C
vel[                     ]vel
 ——→——→timeline——→——→
```

b.

```
    voi
 nas/
  |/
  C   C
   \ /
   vel
```

(8a) shows the OTP representation of /ŋk/. The association lines (Goldsmith 1976) of equivalent (8b) become unnecessary. Instead, constituents whose interiors "overlap in time," such as the velar gesture and either consonant of (8a), are considered to be associated. Gen places constituents such as those in (8a) freely along the continuous timeline, requiring only that edge brackets come in matched pairs and that distinct constituents of the same type (e.g., two syllables or two nas features) not overlap. Any other well-formedness conditions on bracket placement, such as the prosodic hierarchy, are enforced not by Gen but by primitive constraints such as (6d) or perhaps the weaker (7d). This approach keeps Gen simple. There is also empirical support for enforcing at least the prosodic hierarchy with violable constraints (Selkirk 1994, Everett 1996).

In keeping with the principle of Containment (Prince & Smolensky 1993), Gen includes all underlying (input) material in each candidate representation. This material is placed on separate tiers (not shown in (8a)). Primitive constraints such as (6g), (6h), and (7g) can then enforce Correspondence (represented as overlap) between *input* constituents such as $[\underline{voi}]$, notated with an underline, and phonetically interpretable *output* constituents such as $[voi]$.

Indeed, OTP representations constitute an implementation of Correspondence Theory, including McCarthy & Prince's suggestions (1995, 18, 23) that Correspondence should extend to handle autosegmental featural associations. In OTP, Gen marks a candidate's correspondent elements—input and output, segments and features, tones and tone-bearing units—not by *coindexing* them but by having them *overlap on the timeline*. (A representational trick can make Base-Reduplicant correspondences local in this way as well (Clements 1985, Eisner 1997a).)

In summary, the OTP framework is a particularly simple, local and uniform version of Optimality Theory—and Eisner (1997a) shows that it closely matches the subset of OT used in practice. Working within OTP sharply limits the space of grammars that the linguist or the language learner needs to consider. The rest of this paper attempts to show that OTP can produce a fine-grained, explanatory account of the Hayesian stress typology.

4. Basic correspondences of syllables, feet, and stress marks

Let us begin by representing the basic facts about metrical feet, as any theory of prosody must. The simple constraints in (9) establish prosodic-hierarchy relations between feet F and syllables σ (Selkirk 1980a, 1980b, 1984). They put basic restrictions on where feet must and must not appear.

(9) a. FILL-F: ${}_F[\ \rightarrow\ {}_\sigma[\ \ ,\ \ ]_F\ \rightarrow\ ]_\sigma$ (says where feet *can* appear)
"Each foot is strictly built from syllables: it starts and ends on syllable edges (perhaps the edges of different syllables)."

b. PARSE-σ: $\sigma\ \rightarrow\ F$ (says where feet *must* appear)
"Every syllable overlaps with (roughly, is 'linked to') some foot."

For our purposes (9a) is undominated. (9b) is not actually used in the analysis presented here, but it is *a priori* plausible and instructive to discuss. Notice that it permits **sloppy parsing**: it does not say that every syllable is wholly *contained* in a foot.[6] In conjunction with undominated (9a), however, it does have that effect, as (9a) does not allow a syllable to be only partly footed. (It is therefore unnecessary to augment (9b) with $\sigma\ \perp\ {}_F[\,,\ \sigma\ \perp\ ]_F$: "a foot may not start or finish in mid-σ.")

We may use (10) to identify trochaic stress with the left edge of a foot. (For iambic stress, we would use the mirror image of (10), and similarly take the mirror images of all other constraints that name a foot edge.) Note that stress is necessarily treated as a phonological constituent, $\mathtt{x}$. It has edges, width, and an

[6] Sloppy parsing is useful in the analysis of spreading, where a surface feature overlaps the corresponding underlying feature but has a different width. See (6g), which requires only sloppy I-O parsing but can be restricted by further constraints like (7g).

interior, just like any other prosodic constituent or segmental feature. Otherwise none of the primitive constraints could refer to it.[7]

(10) a. PARSE-F: $F \ \to\ \mathtt{x}$ (says where stress *must* appear)
"Any foot bears stress somewhere (overlaps with at least one stress mark)."

b. FILL-x(trochaic): $\mathtt{x}[\ \to\ {}_F[\quad,\quad]_\mathtt{x} \to\ ]_\mu \quad,\quad \mathtt{x}\ \perp\ ]_\sigma$
(says where stress *can* appear)
"Stress only appears at the start of a foot."
"Stress ends on a mora boundary, so extends over some integral number of moras."
"Stress may not extend across (overlap with) a syllable boundary."

With one exception, none of the constraints in (9)–(10) are crucially dominated, that is, they are always observed on the surface (at least for typical languages). Hence I will omit them in tableaux. The exception is (9b), PARSE-σ (which, again, we will not actually need): it is often violated, e.g., in RL trochaic $\sigma(\acute{\sigma}\sigma)(\acute{\sigma}\sigma)$.

All these constraints are quite straightforward, but there is one noteworthy consequence of (10b), following Kager's (1992) analysis of Estonian. In a trochaic system, a stress mark [x] on a heavy syllable may either remain confined to the strong leftmost mora, or else spread to cover the whole syllable. These two cases are illustrated in (11); where the distinction is important, they will be notated as $\acute{-}$ and $\acute{-}\!\acute{}$ respectively. (Note carefully that $\acute{-}\!\acute{}$ does not mean that there are two [x] constituents on the stress tier, but rather one wide one.) The phonetic system is assumed to interpret these forms identically, and the universal constraints given so far do not prefer one over the other.

(11) The types of stress that FILL-x(trochaic) permits on heavy syllables.

a. **Moraic stress, written $\acute{-}$**

$$\begin{array}{ccccccc}
[& & & \sigma & & &] \\
[& & \mathtt{x} & &] & & \\
[& & \mu_s & & [& \mu_w &] \\
[& C & [& V & [& C &]
\end{array}$$

b. **Syllabic stress, written $\acute{-}\!\acute{}$**

$$\begin{array}{ccccccc}
[& & & \sigma & & &] \\
[& & & \mathtt{x} & & &] \\
[& & \mu_s & & [& \mu_w &] \\
[& C & [& V & [& C &]
\end{array}$$

(I follow Zec (1988) in assuming that a light syllable consists of a strong mora, μ_s, while a heavy syllable consists of a strong mora followed by a weak mora, $\mu_s\mu_w$.)

In a moraic language, both forms of stress will appear: e.g., (17a:*f*) avoids stress lapse by using both. However, syllabic stress languages show the influence of a constraint SPREAD-x, which objects to $\acute{-}$ (11a) and prefers $\acute{-}\!\acute{}$. SPREAD-x insists that a stress mark x should spread rightward to cover its entire syllable.

(12) SPREAD-x(trochaic): $]_\mathtt{x}\ \perp\ {}_{\mu_w}[$
"Stress shouldn't end immediately before a weak mora (but may spread onto it)."

[7] For symmetry, one can add the redundant constraints $\mathtt{x}[\ \to\ {}_\mu[$, $\mathtt{x}\ \perp\ {}_\sigma[$ to trochaic (10b). Then the only difference between the trochaic system and its iambic mirror image, so far, lies in the single constraint $\mathtt{x}[\ \to\ {}_F[$. The rest of (9)–(10) is symmetric.

SPREAD-**x** essentially says that *stress has an affinity for weak moras*, μ_w—presumably because it is μ_w that represents syllable weight. (While the formulation in (12) may look odd at first, it is the natural way to express local spreading requirements in OTP; (7f) is another example.)

How about iambic systems? They are the same, in mirror image: [**x**] may either remain on the rightmost mora of —, written —´, or spread leftward to cover both moras. But spreading for iambs is never forced, as it is for syllabic trochees. If it were, we would obtain the unattested case of syllabic ("even") iambs. Why does this not happen? Because stress *already* falls on the weak mora in iambic languages: spreading it does not make it any happier. Neither SPREAD-**x** nor its mirror image can distinguish between the iambic options, —´ and ´—´.[8]

Thus, the desire of stress, **x**, to be supported by a weight-bearing mora, μ_w, leads to a difference between iambic and trochaic systems—the existence of syllabic trochees but not syllabic iambs. In the next section we will see another crucial constraint, WEIGHTEDGE, that is also motivated by this desire.

5. Iambic systems and lapse avoidance

OTP offers at least two ways to ensure that a syllable string receives alternating stress. The word may either attract as *many* stresses as it can bear without stress *clash* (i.e., ANTICLASH $\gg$ STRESSALL), or endure only as *few* as it needs to avoid stress *lapse* (i.e., ANTILAPSE $\gg$ something like STRESSNONE). Either approach contrasts sharply with the non-OTP FTBIN account (see (5) above), which does not make it clear why there can be no FTTERN or FTQUAT constraint.[9]

I will refer to these strategies as STRESSALL-**driven** and ANTILAPSE-**driven**, respectively, according to the constraint that drives the language to do any footing at all. In this section and the next, I develop an ANTILAPSE-driven typology. Later, §8 will examine the virtues of STRESSALL-driven systems.

A stress lapse consists of two successive unstressed syllables. Note that no primitive constraint may refer directly to the *absence* of a stress mark [**x**]. (Stress, like other OTP constituents, is privative; so this is just the common prohibition on reference to zeros (Stanley 1967, Akinlabi 1993).) Nonetheless, OTP can successfully forbid lapse with the following local constraint:

[8] To put this formally, (12) and its mirror image are satisfied *on the surface* for iambic systems. Hence there is no harm done by adding either to a working hierarchy: it can't eliminate the optimal candidate. $]\mathbf{x} \perp {}_{\mu_w}[$ merely blocks ´—, which is already ruled out by FILL-**x**(iambic). Likewise, $\mathbf{x}[\ \perp\ ]_{\mu_w}$ merely asks that ˘́ or ´—´, which (unlike —´) start with stress, not follow a heavy syllable $\mu_s\mu_w$, which ends in a weak mora. Again, other iambic constraints will independently enforce this property.

[9] Similar approaches for metrical stress have been advanced by Prince (1983), who writes that "clash . . . is the major determinant of alternating patterns" (p. 73); by Selkirk (1984), who invokes a constraint against lapses; and by Green & Kenstowicz (1995), whose foot-sensitive LAPSE constraint is an embellishment of (13) and can similarly be expressed in OTP. McCarthy & Prince (1986, 1) propose that "a rule may fix on one specified element and examine an structurally adjacent element and no other."

(13) ANTILAPSE(σ): $(\ ]_\sigma$ and $_\sigma[\ ) \rightarrow (\ ]_{\mathtt{x}}$ or $_{\mathtt{x}}[\ )$
"Every syllable boundary coincides with the edge of a stress mark. That is, adjacent syllables must contrast for stress."

ANTILAPSE has a more complex statement than the other constraints in this paper. While conjunction and disjunction should be used reluctantly in OTP, they are sometimes empirically necessary (e.g., to pick out the class of coronal fricatives or stressed vowels; see Eisner (1997a) for substantive restrictions). What is crucial is that this machinery does *not* compromise the key requirement of OTP, that each violation be triggered in a perfectly local manner. ANTILAPSE(σ) simply targets those instants at which one syllable is ending and another starting, and checks whether other edges fall at those instants.

Two other constraints complete the core of an ANTILAPSE-driven system. They deal with length, and in particular, with a phenomenon we saw earlier in (12): the affinity of stress for weak moras.

(14) WEIGHTEDGE(iambic): $]_F \rightarrow]_{\mu_w}$ (alternatively, $]_{\mathtt{x}} \rightarrow]_{\mu_w}$)
"The stressed (right) edge of a foot should be supported by syllable weight, i.e., by a weak mora."

(15) FILLWEIGHT: $_{\mu_w}[\rightarrow (\ \underline{_S[}$ or $\overline{\underline{_{\mu_w}[}}\ )$
"Don't lengthen: weak moras on the surface must correspond to underlying segments or weak moras.[10]"

WEIGHTEDGE wants stressed syllables to be heavy. This obviously handles iambic lengthening; less obviously, it also helps to explain why heavy syllables are stressed.[11] The idea is that stressing a heavy syllable is unobjectionable, while stressing an underlyingly light syllable violates either WEIGHTEDGE (if we lengthen the syllable) or else the faithfulness constraint FILLWEIGHT (if we do not lengthen). To avoid such violations, we prefer to stress heavies. We will stress (and perhaps lengthen) additional lights only to satisfy ANTILAPSE.

The three crucial constraints (13)–(15) may appear in any order. The resulting system depends only on which constraint is ranked lowest (and hence is violated for the sake of the other two):

(16) a. ANTILAPSE , FILLWEIGHT $\gg$ WEIGHTEDGE:
left-to-right iambs without IL (Seminole/Creek)
b. ANTILAPSE , WEIGHTEDGE $\gg$ FILLWEIGHT:
left-to-right iambs with IL (Choctaw)
c. FILLWEIGHT , WEIGHTEDGE $\gg$ ANTILAPSE:
stress heavies only, via unbounded right-strong feet (Kwakw'ala)

[10] Compare the HEAD-DEP constraint of Alderete (1995), which bars epenthetic stressed vowels. Strictly speaking, (15) should be accompanied by another constraint that checks the right edge of μ_w in the same way, since gemination is a method of lengthening, employed by Algonquian and other languages, that never violates (15).

[11] Contrast Prince (1990), Hung (1994), where weight-to-stress and iambic lengthening are unrelated.

Like the bounded iambic systems, (16c) is—as one would hope—frequently attested. It is (16c) that combines with Prince's (1983) End Rule (§10) to produce quantity-sensitive unbounded stress systems (Prince 1976), such as Kwakw'ala, which assigns primary stress to the leftmost heavy syllable.

The incomplete tableaux shown in (17) illustrate how the three systems work. The STRESSALL constraint is discussed below. As is usual in OT, complete tableaux are far too long to supply,[12] but for all constraint hierarchies discussed in this paper, *complete tableaux for an assortment of inputs* have been constructed and checked (by computer, Eisner 1997b), confirming the predictions.

(17) a. LR iambs without lengthening. Use (19) to eliminate e.

⌣⌣⌣—⌣⌣——⌣⌣⌣	ANTIL	FILLW	WEDGE	STRALL
a. (⌣⌣⌣́)——⌣(⌣—́́)—(⌣⌣́)⌣	*!***		**	********
b. (⌣⌣⌣—́́)⌣(⌣—́́)(—́)⌣⌣⌣	*!****			********
c. ⌣(⌣⌣́)(—́)(⌣⌣́)(—́)(—́)⌣(⌣⌣́)	*!*		***	*****
d. (⌣⌣́)(⌣—́́)(⌣́)(⌣—́́)(—́)(⌣́)(⌣⌣́)			****!	****
♡ e. (⌣⌣́)(⌣—́́)(⌣́)(⌣—́́)(—́)(⌣⌣́)⌣			***	*****
♡ f. (⌣⌣́)(⌣—́́)(⌣⌣́)(—́)(—́)(⌣⌣́)⌣			***	*****
g. (⌣⌣́)(⌣—́)(⌣⌣́)(—́)(—́)(⌣⌣́)⌣	*!		***	*****
h. (⌣⌣́)(⌣—́́)(⌣⌣́)(——́́)(⌣⌣́)⌣			***	******!
i. (⌣—́́)(⌣—́́)(⌣—́́)(—́)(—́)(⌣—́́)⌣		*!**		*****
j. (⌣—́́)(⌣—́́)(⌣—́́)(—́)(—́)(——́́)—		*!****		*****
k. (⌣⌣́)(⌣—́́)(⌣⌣́)(—́)(—́)(⌣́)(⌣́)(⌣́)			****!*	***
l. (⌣⌣́)(⌣—́́)(⌣⌣́)(—́)(—́)(—́)(—́)(—́)		*!**	**	***

b. LR iambs with lengthening.

⌣⌣⌣—⌣⌣——⌣⌣⌣	ANTIL	WEDGE	FILLW	STRALL
a. (⌣⌣⌣́)——⌣(⌣—́́)—(⌣⌣́)⌣	*!***	**		********
b. (⌣⌣⌣—́́)⌣(⌣—́́)(—́)⌣⌣⌣	*!****			********
c. ⌣(⌣⌣́)(—́)(⌣⌣́)(—́)(—́)⌣(⌣⌣́)	*!*	***		*****
d. (⌣⌣́)(⌣—́́)(⌣́)(⌣—́́)(—́)(⌣́)(⌣⌣́)		*!***		****
e. (⌣⌣́)(⌣—́́)(⌣́)(⌣—́́)(—́)(⌣⌣́)⌣		*!**		*****
f. (⌣⌣́)(⌣—́́)(⌣⌣́)(—́)(—́)(⌣⌣́)⌣		*!**		*****
g. (⌣⌣́)(⌣—́)(⌣⌣́)(—́)(—́)(⌣⌣́)⌣	*!	***		*****
h. (⌣⌣́)(⌣—́́)(⌣⌣́)(——́́)(⌣⌣́)⌣		*!**		******
♡ i. (⌣—́́)(⌣—́́)(⌣—́́)(—́)(—́)(⌣—́́)⌣			***	*****
j. (⌣—́́)(⌣—́́)(⌣—́́)(—́)(—́)(——́́)—			****!*	*****
k. (⌣⌣́)(⌣—́́)(⌣⌣́)(—́)(—́)(⌣́)(⌣́)(⌣́)		*!****		***
l. (⌣⌣́)(⌣—́́)(⌣⌣́)(—́)(—́)(—́)(—́)(—́)		*!*	***	***

c. Heavy stress. Other footings yielding these stresses are also fine.

[12] The tableau for (say) ⌣—⌣⌣⌣—⌣ has 112,256 candidates, considering only those that satisfy both (9a) and the iambic version of (10), and whose only faithfulness violations involve syllable lengthening. Note that the underlying form is not really ⌣—⌣⌣⌣—⌣ but something like ʃə*bumbababaran*ʔə. Gen does produce candidates with syllabification or moraification other than ⌣—⌣⌣⌣—⌣, but I assume these are always eliminated by higher-ranked constraints (i.e., syllabification is not compromised to satisfy metrical requirements).

⌣⌣⌣—⌣⌣——⌣⌣⌣	FILLW	WEDGE	ANTIL	STRALL
a. (⌣⌣⌣́)—⌣(⌣—́́)—(⌣⌣́)⌣		*!*	****	********
♡ b. (⌣⌣⌣—́́)⌣(⌣—́́)(—́)⌣⌣⌣			*****	********
c. ⌣(⌣⌣́)(—́)(⌣⌣́)(—́)(—́)⌣(⌣⌣́)		*!**	**	*****
d. (⌣⌣́)(⌣—́́)(⌣́)(⌣—́́)(—́)(⌣́)(⌣⌣́)		*!***		****
e. (⌣⌣́)(⌣—́́)(⌣́)(⌣—́́)(—́)(⌣⌣́)⌣		*!**		*****
f. (⌣⌣́)(⌣—́́)(⌣⌣́)(—́)(—́)(⌣⌣́)⌣		*!**		*****
g. (⌣⌣́)(⌣—́)(⌣⌣́)(—́)(—́)(⌣⌣́)⌣		*!**	*	*****
h. (⌣⌣́)(⌣—́́)(⌣⌣́)(——́́)(⌣⌣́)⌣		*!**		******
i. (⌣—́́)(⌣—́́)(⌣—́́)(—́)(—́)(⌣—́́)⌣	*!**			*****
j. (⌣—́́)(⌣—́́)(⌣—́́)(—́)(—́)(——́́)—	*!****			*****
k. (⌣⌣́)(⌣—́́)(⌣⌣́)(—́)(—́)(⌣́)(⌣́)(⌣́)		*!****		***
l. (⌣⌣́)(⌣—́́)(⌣⌣́)(—́)(—́)(—́)(—́)(—́)	*!**	**		***

A low-ranked constraint, STRESSALL, is needed to break ties:

(18) STRESSALL: $\sigma \longrightarrow \mathtt{x}$ (alternatively, $]_\sigma \longrightarrow]_F$ or $_\sigma[\longrightarrow {}_F[$)
"Other things equal, have as many feet as possible (where feet and stresses are in 1-1 correspondence)."

STRESSALL ensures that we will have stress wherever (13)–(15) do not actively discourage it—in particular, on all heavy syllables. ANTILAPSE already begs for stress on most heavy syllables (and in §6 we will see a moraic version that begs for stress on all). However, we need STRESSALL to decide in favor of heavy stress when ANTILAPSE is indifferent. For example, STRESSALL guarantees stress on a word consisting of a lone heavy. It also stresses both of two successive heavies, choosing (—́)(—́) over alternatives such as *—(—́́), *(——́́), and *(—́)—, which satisfy (13)–(15) equally well. Such tie-breaking can be seen in (17a:*h*).

Note that unwanted clashing candidates such as (17a:*e*) tie with the usual pattern of LR iambs (17a:*f*). We easily eliminate such candidates with a further mirroring constraint BRANCH, ranked anywhere, that rules out all degenerate feet and thereby rules out stress clash. In general BRANCH seems to be inviolable, even in cases (discussed in §10) commonly analyzed as having peripheral degenerate feet. However, see footnote 17 for a possible use of the eliminated candidates.

(19) BRANCH(iambic): $\mathtt{x}[\perp {}_F[$ [compare the iambic version of (10)]
"Just as the right edge of an iambic foot insists on stress, the left edge absolutely rejects it. Hence stress may not consume the entire foot, but must alternate."

6. Trochees with ANTILAPSE

To get RL syllabic trochees, we need only take the mirror image of the iambic system. The key insight is that the trochaic mirror image of WEIGHTEDGE must be *violated for every foot*, because the higher-ranked prosodic hierarchy makes it impossible to satisfy:

(20) WEIGHTEDGE(trochaic): $_F[\ \rightarrow\ _{\mu_w}[$ (alternatively, $\mathtt{x}[\ \rightarrow\ _{\mu_w}[$)
“The stressed (left) edge of a foot should be supported by syllable weight, i.e., by a weak mora. [Thus, it must start in mid-$(\mu_s\mu_w)_\sigma$.]”

Put another way, speakers like to sustain the stressed end of a foot, but it is much harder to do that for trochees. A trochaic version of (3) would not surface as *(ččíha)(bbína)(ččíli)*. Extra length μ_w cannot be added at the left of a foot, nor is an underlying source of such length available to attract feet.

In syllabic trochee systems, therefore, WEIGHTEDGE ends up discouraging feet, and stresses, without regard to syllable quantity. This single change yields the striking differences between iambs and syllabic trochees. We saw that while iambic WEIGHTEDGE discouraged $\acute\sigma$ in general, it turned a blind eye to —̋; trochaic WEIGHTEDGE discourages all $\acute\sigma$. Thus iambic systems can stress adjacent heavy syllables without violating WEIGHTEDGE, whereas for syllabic trochees, WEIGHTEDGE quite correctly objects to this. In addition, lengthening ⏑́ lets it escape WEIGHTEDGE’s notice in iambic systems, but not in trochaic ones—explaining the absence of phonological Trochaic Lengthening.[13]

What trochaic systems do the possible rankings yield? If ANTILAPSE(σ) $\gg$ WEIGHTEDGE, we stress as many syllables as necessary to avoid lapse, but no more. This results in bisyllabic feet, as desired: it takes fewer copies of $(\acute\sigma\sigma)$ than of $(\acute\sigma)$ (e.g., (—́)) to cover a word. Syllabic stress is automatically preferred on heavy syllables, since ANTILAPSE allows (—̋σ) but not (—́σ). However, SPREAD-x (ranked anywhere) is also needed—to break the tie between (⏑́—) and *⏑(—́).

(21) Syllabic trochees. (SPREAD-x is not shown.)

⏑⏑⏑—⏑⏑——⏑⏑⏑	ANTIL	WEDGE	FILLW	STRALL
a. ⏑(⏑́⏑)—(—̋⏑)⏑—(⏑́⏑⏑)	*!***	***		********
b. ⏑⏑⏑(—́)(—̋⏑)⏑(—̋⏑⏑⏑)	*!****	***		********
c. (⏑́⏑)⏑(—́)(—́)(⏑́⏑)(—́)(⏑́⏑)⏑	*!*	******		*****
d. (⏑́⏑)(⏑́)(—́)(—̋⏑)(⏑́)(—̋⏑)(⏑́⏑)		******!*		****
e. ⏑(⏑́⏑)(—́)(—̋⏑)(⏑́)(—̋⏑)(⏑́⏑)		******!		*****
f. ⏑(⏑́⏑)(—́)(—́)(⏑́⏑)(—̋⏑)(⏑́⏑)		******!		*****
g. ⏑(⏑́⏑)(—́)(—́)(⏑́⏑)(—́⏑)(⏑́⏑)	*!	******		*****
♡ h. ⏑(⏑́⏑)(—̋—)(⏑́⏑)(—̋⏑)(⏑́⏑)		*****		******
i. ⏑(—̋⏑)(—́)(—́)(—̋⏑)(—̋⏑)(—̋⏑)		******!	***	*****
j. —(—̋—)(—́)(—́)(—̋⏑)(—̋⏑)(—̋⏑)		******!	*****	*****
k. (⏑́)(⏑́)(⏑́)(—́)(—́)(⏑́⏑)(—̋⏑)(⏑́⏑)		******!**		***
l. (—́)(—́)(—́)(—́)(—́)(⏑́⏑)(—̋⏑)(⏑́⏑)		******!**	***	***

If on the other hand WEIGHTEDGE $\gg$ ANTILAPSE(σ) as in (16c), a ranking that should be permitted for trochees because it is for iambs, then the optimal candidate has no feet at all. Fortunately, languages that stress nothing (or

[13] Hence the ranking of FILLWEIGHT does not matter for trochees: there is never any motivation to violate it.

everything) are indeed frequently attested: they are just languages without secondary stress contrasts. The constraints of §10 can still assign regular initial or final *primary* stress. Many such simple stress systems exist (see Hyman 1977).

Now let us turn to moraic trochees. They differ empirically from syllabic ones in that they avoid stress lapses not only between adjacent syllables, but between any pair of adjacent moras. In particular, all heavy syllables must be stressed, either as ´— or ´´—, to avoid an internal lapse. We may produce a RL moraic trochee system by replacing ANTILAPSE(σ) with ANTILAPSE(μ):

(22) ANTILAPSE(μ): $(\,]_\mu$ and $_\mu[\,) \;\rightarrow\; (\,]_{\mathtt{x}}$ or $_{\mathtt{x}}[$ or $\mathtt{x})$
"Every mora boundary coincides with the edge of a stress mark (or falls within a wide stress mark, as in ´´—)."

(23) Moraic trochees. Again, BRANCH will eliminate candidate e.

⌣⌣⌣—⌣⌣⌣——⌣⌣⌣⌣	ANTIL	WEDGE	FILLW	STRALL
a. ⌣(´⌣⌣)—(´´—⌣)⌣—(´⌣⌣⌣)	*!*****	***		********
b. ⌣⌣⌣(´—)(´´—⌣)⌣(´´—⌣⌣⌣)	*!****	***		********
c. (´⌣⌣)⌣(´—)(´—)(´⌣⌣)(´—)(´⌣⌣)⌣	*!*	******		*****
d. (´⌣⌣)(´⌣)(´—)(´´—⌣)(´⌣)(´´—⌣)(´⌣⌣)		*******!		****
♡ e. ⌣(´⌣⌣)(´—)(´´—⌣)(´⌣)(´´—⌣)(´⌣⌣)		******		*****
♡ f. ⌣(´⌣⌣)(´—)(´—)(´⌣⌣)(´´—⌣)(´⌣⌣)		******		*****
g. ⌣(´⌣⌣)(´—)(´—)(´⌣⌣)(´—⌣)(´⌣⌣)	*!	******		*****
h. ⌣(´⌣⌣)(´´——)(´⌣⌣)(´´—⌣)(´⌣⌣)	*!	*****		******
i. ⌣(´´—⌣)(´—)(´—)(´´—⌣)(´´—⌣)(´´—⌣)		******	*!**	*****
j. —(´´——)(´—)(´—)(´´—⌣)(´´—⌣)(´´—⌣)	*!*	******	*****	*****
k. (´⌣)(´⌣)(´⌣)(´—)(´—)(´⌣⌣)(´´—⌣)(´⌣⌣)		*******!*		***
l. (´—)(´—)(´—)(´—)(´—)(´⌣⌣)(´´—⌣)(´⌣⌣)		*******!*	***	***

Note that even in these moraic trochee systems, syllabic stress ´´— may surface, as in (23f). This is not due to the influence of SPREAD-x, which must be universally ranked below ANTILAPSE(μ) and has no effect here. Rather, ANTILAPSE itself makes syllabic stress optimal on a heavy that precedes an odd string of lights: candidate (f) is chosen over (g) or (c) to avoid lapse. This forces RL footing, and achieves the attested RL stress pattern, though via a *non*-Hayesian analysis—the "mirror iamb" (´´—⌣). The footing exactly mirrors the iambic system of (17a), where lapse avoidance resulted in the syllabically-stressed, Hayesian iamb (⌣´´—) and a LR stress pattern.

We have now seen that the same system yields syllabic or moraic trochees according to the choice of ANTILAPSE(σ) or ANTILAPSE(μ), and that the mirror of the ANTILAPSE(σ) version yields iambs. We must also consider the mirror of the ANTILAPSE(μ) version: is it attested? The answer turns out to be yes: it too is iambic. That is, for the iambic systems in (16), the choice between the two versions of ANTILAPSE makes absolutely no difference.[14]

[14]Why should this be? Kager (1993) observes that if we consider only surface stress, leaving aside

7. An iambic lengthening paradox, and LR trochees

The system of §5–§6 is typologically attractive in that if we *freely rank* the constraints (13)–(19) or their mirror images, and optionally substitute ANTILAPSE(μ) for ANTILAPSE(σ), we derive exactly the following systems:

- LR iambs with and without lengthening
- unbounded stress systems that stress all heavy syllables
- RL syllabic and moraic trochees
- simple degenerate systems without a secondary stress contrast (ranking STRESSALL high stresses everything; ranking WEIGHTEDGE(trochaic) high stresses nothing)

However, there are two deficiencies in the system as stated. First, to secure the above result, we must resolve a ranking paradox involving iambic lengthening. Second, the typology does not yet generate LR trochees.

The facts of LR iambic lengthening languages such as Choctaw present a curious ranking paradox. Example (24a) suggests that rather than leave a stray light syllable, the word is willing to suffer both a faithfulness violation (lengthening) and a possibly suboptimal foot ($(\acute{-})$). The desire to foot the stray $\smile$ is apparently ranked high enough to overcome these obstacles.[15]

(24) a. Input: $\smile\smile-$ Output: $(\smile\acute{-})(\acute{-}) \succ *\smile(\smile\acute{-})$
b. Input: $\smile$ Output: $*(\acute{-}) \prec \smile$
c. Input: $\smile\smile\smile$ Output: $*(\smile\acute{-})(\acute{-}) \prec (\smile\acute{-})\smile$

But given such a preference, why is the same decision not made in (24b–c)? Shouldn't the phonology again prefer to lengthen and foot the stray syllable—at the same cost, namely, one additional lengthened syllable and one suboptimal $(\acute{-})$?

The ANTILAPSE-driven approach above provides a partial explanation: stray syllables are footed only as necessary to avoid a stress lapse. (24a) is a case where lengthening is worthwhile because it avoids a lapse. No lapse is at issue in (24b–c), whose winning candidates are lapse-free despite their stray syllables.

lengthening and the conflicting theoretical claims about foot shape (e.g., mirror iambs) and position, LR iambs are perfect mirrors of RL moraic trochees. So it should not be surprising that moraic trochees (with ANTILAPSE(μ)) mirror to an iambic system. As for syllabic trochees, they differ from moraic ones only because ANTILAPSE(σ) does not demand that heavy syllables be stressed, while ANTILAPSE(μ) does. This difference has no observable effect in the iambic mirror image, where WEIGHTEDGE(iambic) and STRESSALL stress heavies even without help from ANTILAPSE.

[15] One might wonder whether it is instead a (non-primitive) Generalized Alignment constraint that selects $(\smile\acute{-})(\acute{-})$ over $*\smile(\smile\acute{-})$. The answer is no: both ALIGN-L(F,*PrWd*) and ALIGN-R(F,*PrWd*) incorrectly favor $*\smile(\smile\acute{-})$.

However, this explanation leaves a residue. It does not explain why (24a) chooses $(\smile\acute{-})(\acute{-})$ over yet another candidate, $*(\acute{-})(\smile\acute{-})$. Under rankings like (16b), these two choices simply tie. For a longer example, consider underlying $\smile\smile\smile\smile-\smile\smile$. *No local well-formedness constraint* can distinguish between the candidates $(\smile\acute{-})(\smile\acute{-})(\acute{-})(\smile\acute{-})$ and $*(\smile\acute{-})(\acute{-})(\smile\acute{-})(\smile\acute{-})$, which are apparently identical on the surface except for the order of two word-internal feet.

One, rather arbitrary solution is to introduce a low-ranked, *non*-local constraint just to break the tie: ALIGN-R$(F, PrWd)$ or ALIGN-R$(-, PrWd)$. Such constraints are not allowed within the OTP framework. It seems a pity to add them for such a small role. Nor can they play a big role: these data simply do not yield to an GA-style account. Adopting alignment wholesale would mean ranking ALIGN-L highly in order to explain LR footing (consider (24c), which surfaces as $(\smile\acute{-})\smile$ not $*\smile(\smile\acute{-})$); but this would sabotage the tie-breaker ALIGN-R.

A second line of attack supposes that these two candidates are *not* in fact identical on the surface—that "added" length is phonologically distinct from "parsed" length. Hayes (1995, p. 269) remarks that when both types of length exist in an IL language, they are sometimes phonetically distinct (Choctaw, Chickasaw, St. Lawrence Island Yupik). If the system were modified to represent two types of length, we could ban just those surface $(\acute{-})$ feet that are "underlyingly degenerate": well-formedness constraints could recognize them as $(\acute{\smile})$ feet padded with length of the merely "added" variety. (Such $(\acute{-})$ feet are blocked similarly in derivational accounts, where they can only arise if degenerate $(\acute{\smile})$ can be created before lengthening applies (Hayes 1985, 1995, Kager 1993).)

A third solution, adopted here, is to go beyond well-formedness constraints and use a local **input-output** (**I-O**) constraint, SUPPORT-`x`. Again, the idea is to state that $(\acute{-})$ is a bad foot just if it corresponds to underlying $\smile$. Such bad feet never surface in IL systems or indeed in any system (except to rescue subminimal words), so SUPPORT-`x` may be ranked arbitrarily high; on the other hand, it is presently only needed to break ties, so lower rankings will work equally well.

(25) SUPPORT-`x`: $\mathtt{x} \rightarrow \underline{S}$ [this formulation assumes representation in (26)]
"A stress mark must be supported by at least one underlying segment. (S abbreviates 'C or V,' or perhaps refers to a segment-root 'feature.')"

(26)
$$\begin{array}{llllll}
 & & & [& \mathtt{x} &] \\
[& & \mu_s &][& \mu_w &] \\
[& C &][& V & &] \\
[& \underline{C} &][& \underline{V} &] &
\end{array}$$
(representation of lengthened $CV\!\acute{:}$)

In particular, $(\acute{-})$ violates SUPPORT-`x` just in lengthened cases like (26), where the stress mark rests entirely on epenthetic material—the second half of a lengthened vowel or the first half of a geminated consonant. $(\acute{\acute{-}})$ is not a possible alternative: while the wider stress mark does satisfy SUPPORT-`x`, it is already ruled out by BRANCH. The iambic feet $(\smile\acute{\smile})$, $(\smile\acute{\acute{-}})$ (even when lengthened from $\smile\smile$), and non-lengthened $(\acute{-})$ survive both constraints.

Notice that while (25) is an I-O constraint, it is *not* strictly a faithfulness constraint. Nor can it be: faithfulness cannot distinguish the candidates in the $\smile\smile\smile\smile{-}\smile\smile$ case above, each of which lengthens just one syllable. McCarthy & Prince (1994, p. 22) speculate that I-O constraints may exist that do not resemble faithfulness, and there are precedents for this. For example, Cole & Kisseberth (1994) do not parse underlying $\underline{\text{ATR}}$ into surface ATR ($\underline{\text{ATR}} \rightarrow$ ATR), but rather into another, phonetically invisible constituent called an "ATR domain" ($\underline{\text{ATR}} \rightarrow$ ATR*dom*); and several authors have proposed finely-tuned "positional faithfulness" constraints that are sensitive to local prosody (e.g., Steriade 1995, McCarthy 1995, Lombardi 1995).[16]

A more serious problem with the ANTILAPSE-driven approach of §5–§6 is directionality. The ANTILAPSE-driven approach correctly predicts that all iambs are LR. However, it also predicts that all trochees are RL, which is patently false.

To see what is odd about the well-attested case of LR trochees, define an **alignment domain** or *ADom* to be a maximal string of $\smile$'s (the moraic case) or simply of σ's (the syllabic case). To get LR trochees, we must actually *force a lapse* at the right end of every odd-length alignment domain: $(\acute{-})\smile$ or $(\acute{-})(\acute{\smile}\smile)\smile(\acute{-})$ (moraic), $(\acute{\sigma}\sigma)(\acute{\sigma}\sigma)\sigma$ (syllabic). By contrast, an even-length alignment domain is exhaustively footed: $(\acute{-})(\acute{\smile}\smile)(\acute{\smile}\smile)(\acute{-})$.

There are various adjustments that can force LR trochees over the objections of ANTILAPSE. One approach is to add constraints to the existing hierarchy. (For example, something like ${}_{ADom}[\ \rightarrow\ {}_{F}[$ or ${}_{ADom}[\ \rightarrow \mathbf{x}[$ would attempt to restart footing at the left edge of an alignment domain, while $]_{ADom} \perp\ ]_{F}$, discussed below, would break ties by encouraging any resulting lapse to fall at the right edge of the domain rather than in the middle.[17]) A related approach involves

[16] Another interesting example of a necessary non-faithfulness I-O constraint is provided by Trochaic Shortening, provided that this occurs (as Hayes would predict) with LR (not just RL) moraic trochees:

(i) a. Underlying $\smile\smile\smile\smile\smile\smile \Rightarrow$ surface $(\acute{\smile}\smile)(\acute{\smile}\smile)\smile\ \succ\ (\acute{\smile}\smile)\smile(\acute{\smile}\smile)$
b. Underlying $\smile\smile\smile{-}\smile \Rightarrow$ surface $(\acute{\smile}\smile)(\acute{\smile}\smile)\smile\ \prec\ (\acute{\smile}\smile)\smile(\acute{\smile}\smile)$

The faithfulness constraints PARSEWEIGHT and FILLWEIGHT do not distinguish the candidates either in (a) or in (b). Thus, if these are the only I-O constraints available, it must be a well-formedness (O) constraint that breaks the tie in each case. But this is impossible, for the highest-ranked O constraint to distinguish $(\acute{\smile}\smile)(\acute{\smile}\smile)\smile$ from $(\acute{\smile}\smile)\smile(\acute{\smile}\smile)$ would break both the ties in favor of the same output.

We must conclude that other I-O constraints are available. These could be faithfulness constraints, since we could stress all heavy syllables in the lexicon and just use PARSESTRESS: $\underline{\mathbf{x}} \rightarrow \mathbf{x}$. Such a lexical redundancy rule would complicate the learning problem, however, and barring it we appear to need a non-faithfulness I-O constraint. We might say that underlying length projects surface stress (e.g., $\underline{\mu_w} \rightarrow \mathbf{x}$), or that it is more important to parse it at the weak edge of a foot (e.g., $(\,\underline{]_{\mu_w}}$ and $]_F\,) \rightarrow\ ]_{\mu_w}$).

[17] It is an intriguing possibility that in iambic systems, the same (unmirrored) constraint ${}_{ADom}[\ \rightarrow \mathbf{x}[$ might be responsible for the unusual stress systems of Tübatulabal, Aklan, and Tiberian Hebrew. Kager (1989) shows that these systems can be analyzed as moraic trochees plus final main stress. Other analyses (Crowhurst 1991, Kager 1993), suggest that they are RL iambic—an otherwise unattested case—but allow degenerate feet at the left edge of each alignment domain, in part to avoid lapse: $(\acute{-})(\acute{\smile})(\smile\acute{\smile})(\acute{-})(\acute{\smile})$ rather than $*(\acute{-})\smile(\smile\acute{\smile})(\acute{-})\smile$. Both analyses are possible for us: the former may be arranged as in §10, while the latter emerges as candidate (17a:*d*) if BRANCH and WEIGHTEDGE are dominated by ${}_{ADom}[\ \rightarrow \mathbf{x}[$.

replacing ANTILAPSE(σ) or ANTILAPSE(μ) with yet another parametric variant, such as ${}_{\mu}[\ \rightarrow\ (\,]_{\mathtt{x}}$ or $\mathtt{x}[\,)$), that does not have a RL directionality preference.

In the next section, we will examine a more interesting and perhaps neater approach that relies on more freely reranking the constraints of §5–§6.

8. Driving LR trochees and more with STRESSALL

The central proposal of this section is that both LR trochees *and* final-syllable extrametricality result from an *undominated* NONFINALITY constraint:

(27) NONFINALITY: $]_{ADom} \perp\ ]_F$
"The rightmost syllable of an alignment domain may not be footed."

The effect of this constraint will depend on where *ADom* constituents are constrained to appear (possibly nowhere). I assume that NONFINALITY *does not mirror*—that it takes exactly the form in (27) for both iambic and trochaic systems. In this respect, it resembles ordinary universal constraints such as ONSET and NOCODA. It does not class with the other asymmetric constraints proposed in this paper: FILL-F, BRANCH, WEIGHTEDGE, and (optionally) SPREAD-$\mathtt{x}$. (Perhaps this is because it is not involved in foot form, or because it does not mention $\mathtt{x}$.)

An asymmetry like this is necessary in any system, to account for the fact that extrametrical syllables are overwhelmingly *word-final*. (Hayes (1995, 74) writes that the only well-motivated exception is Kashaya (Buckley 1991).) Provided that NONFINALITY causes extrametricality, its inability to mirror simply states this asymmetry.

We will see shortly that NONFINALITY has a second effect: it can favor LR footing. Its inability to mirror therefore makes a second prediction—the absence of RL iambs. As we will see, ANTILAPSE and NONFINALITY simply *concur* that iambs should be LR. For trochees, by contrast, they compete to enforce RL and LR respectively. The absence of RL iambs is of course a serious problem for *parametric* accounts of directionality, whether iterative (Hayes 1995) or based on Generalized Alignment (McCarthy & Prince 1993).

Unifying these two asymmetries—extrametricality and directionality—is not mere sophistry. There is a powerful reason to use the same constraint NONFINALITY to explain both LR trochaism and final syllable extrametricality: namely, these properties appear to be in *complementary distribution*. Hayes (1995) lists 32 trochaic languages that are LR, and 21 trochaic languages with final-syllable extrametricality, yet there is no overlap. In particular, no language assigns preantepenultimate stress on even strings, $(\acute{\sigma}\sigma)(\acute{\sigma}\sigma)\sigma\langle\sigma\rangle$, but not on odd strings, $(\acute{\sigma}\sigma)(\acute{\sigma}\sigma)\langle\sigma\rangle$.[18]

[18] Preantepenultimate main stress is not empirically impossible, so long as its position (relative to the right edge) is unaffected by string length. For the several cases of this sort, Hayes uses RL trochees

Again, this is a serious gap for the parametric accounts (and to my knowledge, one that has not been pointed out before). LR iterative footing (or ALIGN-L) should combine easily with right extrametricality (or $]_{PrWd} \perp]_F$). Indeed, these properties *do* combine in the iambic case, specifically in Hixkaryana and Asheninca (Hayes 1995, 288, 206). Yet they never combine for trochees.

The gap is immediately predicted by the present system, in which the complementary phenomena result from the same local constraint. To achieve the double stray at the end of $(\acute{\sigma}\sigma)(\acute{\sigma}\sigma)\sigma\langle\sigma\rangle$, NONFINALITY would have to keep feet off the last *two* syllables—one for extrametricality, and one for the LR lapse. But NONFINALITY is merely a local constraint. It can push feet away from the end of the word, but (unlike ALIGN-L) it cannot influence how *far* they are pushed. In particular, it is just as satisfied by the RL candidate, $\sigma(\acute{\sigma}\sigma)(\acute{\sigma}\sigma)\langle\sigma\rangle$—which then wins because it violates ANTILAPSE only once.

Having motivated the approach, let us turn to the details of the system. A key property of LR footing is that it sometimes overrides whatever mechanism C blocks footing of the final syllable (assuming there is such a mechanism). Specifically, on *even*-length alignment domains, $(\acute{\sigma}\sigma)(\acute{\sigma}\sigma)$ is exhaustively footed. This suggests that STRESSALL $\gg C$. Extrametricality, by contrast, requires $C \gg$ STRESSALL so that the final syllable is *always* unfooted: $\sigma(\acute{\sigma}\sigma)\sigma$.

If this analysis is correct (rather than the suggestions in §7), LR trochees require what §5 called a STRESSALL-driven hierarchy. We just saw that LR trochees require STRESSALL $\gg C$ to prevent lapses on even-length alignment domains. They also need $C \gg$ ANTILAPSE to override the preference for RL trochees. Therefore STRESSALL $\gg$ ANTILAPSE. This yields a STRESSALL-driven approach, in contrast to the ANTILAPSE-driven approach of §5–§6.

At the start of §7, I mentioned in passing that we could freely rerank the proposed constraints and still get attested systems. For example, some languages might be STRESSALL-driven while others are ANTILAPSE-driven. Which are the systems generated when STRESSALL is highly ranked—specifically, when STRESSALL $\gg$ WEIGHTEDGE, meaning that the desire to add stresses outranks the desire to suppress them?

Such rankings yield either simple degenerate systems, where STRESSALL forces every syllable to be stressed, or *new ways* of generating iambs and trochees. Iambs and trochees arise again if STRESSALL is not given a free hand to stress everything: rankings with BRANCH $\gg$ STRESSALL force alternating stress.[19] For example, if BRANCH and SUPPORT-**x** are undominated, the results of (17) and (23) can be perfectly reproduced by exchanging the positions of STRESSALL and ANTILAPSE. The case corresponding to (17a) is shown below.

(28) LR iambs without lengthening: STRESSALL-driven version.

---

plus final-*foot* extrametricality, $\cdots(\acute{\sigma}\sigma)\langle(\acute{\sigma}\sigma)\rangle$, which is discussed in §10.

[19] At least, if we assume the universal ranking proposed in (34b) below.

(Highest-ranked BRANCH (not shown) eliminates d, e, k, l.)

⏑⏑⏑—⏑⏑——⏑⏑⏑	STRALL	FILLW	WEDGE	ANTIL
a. (⏑⏑⏑́)—⏑(⏑—́́)—(⏑⏑́)⏑	******!**		**	****
b. (⏑⏑⏑—́́)⏑(⏑—́́)(—́)⏑⏑⏑	******!**			*****
c. ⏑(⏑⏑́)(—́)(⏑⏑́)(—́)(—́)⏑(⏑⏑́)	*****		***	*!*
d. (⏑⏑́)(⏑—́́)(⏑́)(⏑—́́)(—́)(⏑́)(⏑⏑́)	****		****	
e. (⏑⏑́)(⏑—́́)(⏑́)(⏑—́́)(—́)(⏑⏑́)⏑	*****		***	
♡ f. (⏑⏑́)(⏑—́́)(⏑⏑́)(—́)(—́)(⏑⏑́)⏑	*****		***	
g. (⏑⏑́)(⏑—́)(⏑⏑́)(—́)(—́)(⏑⏑́)⏑	*****		***	*!
h. (⏑⏑́)(⏑—́́)(⏑⏑́)(——́́)(⏑⏑́)⏑	******!		***	
i. (⏑—́́)(⏑—́́)(⏑—́́)(—́)(—́)(⏑—́́)⏑	*****	*!**		
j. (⏑—́́)(⏑—́́)(⏑—́́)(—́)(—́)(——́́)—	*****	*!****		
k. (⏑⏑́)(⏑—́́)(⏑⏑́)(—́)(—́)(⏑́)(⏑́)(⏑́)	***		*****	
l. (⏑⏑́)(⏑—́́)(⏑⏑́)(—́)(—́)(—́)(—́)(—́)	***	***	**	

Now let us consider how NONFINALITY affects these STRESSALL-driven systems. If there are no *ADom* constituents, or if their placement is not affected by sufficiently high-ranked constraints, then NONFINALITY will have no effect. I suggest the following constraints to control the placement of alignment domains:

(29) FILL-*ADom*: ${}_{ADom}[\ \rightarrow\ {}_{\sigma}[\quad,\quad]_{ADom}\ \rightarrow\ ]_{\sigma}$
"An alignment domain consists of one or more syllables."

(30) ADOMINCLUDE: $\sigma\ \rightarrow\ ADom$
"Every syllable must be parsed into an alignment domain. (Roughly, alignment domains should be maximal.)"

(31) ADOMEXCLUDE: $ADom\ \perp\ \mu_w$
"Alignment domains are interrupted by weak moras (hence by heavy syllables)."

FILL-*ADom* is undominated (as is NONFINALITY). The ranking of ADOMINCLUDE governs where alignment domains are created, and thereby determines where undominated NONFINALITY holds sway. Consider for example the following rankings, in a moraic trochee language:

(32) a. <u>ADOMINC</u> $\gg$ STRESSALL $\gg$ ADOMEXC $\gg$ ANTILAPSE(μ):
RL with right extrametr. (one *ADom* covers whole word[20])

b. STRESSALL $\gg$ <u>ADOMINC</u> $\gg$ ADOMEXC $\gg$ ANTILAPSE(μ):
an unattested system similar to (32d); described below

c. STRESSALL $\gg$ ADOMEXC $\gg$ <u>ADOMINC</u> $\gg$ ANTILAPSE(μ):
LR (a separate *ADom* covers each string of light syllables)

d. STRESSALL $\gg$ ADOMEXC $\gg$ ANTILAPSE(μ) $\gg$ <u>ADOMINC</u>:
RL (foot placement determined entirely by ANTILAPSE;
ADom(s) fall where they may)

[20]To rank ADOMINCLUDE highly is to allow only candidates that are fully parsed into alignment domains. ADOMINCLUDE is equally happy with one long *ADom* or several abutting narrow ones. However, no constraint in (32a) actively prefers, say, $\{\sigma\sigma\}\{\sigma\}$ to $\{\sigma\sigma\sigma\}$, so we may safely ignore the multiple-abutting-*ADom* candidates: they are never more optimal than their corresponding single-*ADom* candidates, although they may tie.

ANTILAPSE still forces RL footing in (32), except as overridden. Note that (32) respects the universal ranking STRESSALL $\gg$ ADOMEXCLUDE, which ensures that we do not get a word-internal analogue of extrametricality (i.e., final lapse on *every ADom*, so *(—́́⌣)(⌣́⌣)⌣(—́) beats (—́)(⌣́⌣)(⌣́⌣)(—́)). For if ADOMINCLUDE is ranked highly enough to reduce the number of feet, i.e. above STRESSALL, then it will also outrank ADOMEXCLUDE. The word can then be covered with one *ADom*, so NONFINALITY need force only a word-final lapse.

9. Free reranking, and mora-stacking languages

Like other constraints we have seen, those in §8 can be reranked quite freely. Not only are ANTILAPSE-driven rankings (17), (23) attested as well as STRESSALL-driven rankings such as (28), but we can see, for instance, that ADOMEXCLUDE could be lowered without effect in (32a,d).

Consider what happens if we freely rerank *all* the moraic trochee constraints that are *ever* violated, shown in (33), except that reranking is subject to universal (34):

(33) STRESSALL, ANTILAPSE(μ), WEIGHTEDGE, FILLLENGTH, ADOMINCLUDE, ADOMEXCLUDE, $]_{ADom} \perp F$

(34) a. STRESSALL $\gg$ ADOMEXCLUDE. [No word-internal extrametricality.]

b. FILLLENGTH $\gg$ STRESSALL. [Bars debatable degenerate systems.[21]]

c. FILLLENGTH $\gg$ $]_{ADom} \perp F$. [Or unneeded *ADom*'s may have power.[22]]

Everything in (33) is of course to be outranked by the undominated constraints discussed earlier, and by BRANCH and SUPPORT-**x**. If we also assume the universal restrictions in (34), then an exhaustive check by computer confirms that *precisely the desired moraic trochee systems* are generated, plus a single unattested system, (32b). (This system is just like RL footing, but if the word contains any odd light strings, the rightmost one of these is footed LR.)

---

[21] A language can simultaneously satisfy STRESSALL and BRANCH without alternating stress, by lengthening every syllable to (—́). (34b) is designed to prevent such languages. Another way to prevent them would be a version of SUPPORT-**x** that disallowed underlyingly degenerate trochees (—́) as well as iambs (—́): one possibility (under certain representational assumptions) is $F \rightarrow]_{\underline{V}}$.

What would a language that lengthened everything to (—́) look like? Answer: —́—̀—̀—̀ or —̀—̀—̀—́, assuming that primary stress is assigned by End Rule Left or End Rule Right (§10). These are just simple languages with no stress *or* length contrast; they would not pose a problem for our theory. However, with ADOMINCLUDE $\gg$ STRESSALL, extrametricality allows two more (unattested) possibilities: —́—̀—̀⌣ and —̀—̀—́⌣. It is possible that such languages do exist, but that the word-final relaxation has been misdiagnosed as a phonetic effect. If so, (34b) could be eliminated, and the resulting languages would simply reproduce an old typological observation (at least for quantity-free languages): Hyman (1977) counts 114 languages where main stress regularly falls in initial position, 77 and 97 where it is penultimate or ultimate, and only 12 where it is regularly peninitial.

[22] The constraint $]_{ADom} \perp F$ is needed somewhere to break ties: for example, if (32c) lacks this constraint, then {(—́)(⌣́⌣)⌣}(—́) ties with *{(—́)(⌣́⌣)(⌣́}—), where { } denotes an *ADom*. But it must not be ranked above FILLLENGTH, or it can distort the shape of a word even in systems, like (32d), where we expect *ADom*'s to be irrelevant. To mention one example, if (32d) continues with "$\cdots \gg\ ]_{ADom} \perp F \gg$ FILLLENGTH," then on input ⌣⌣, *{⌣́}(—́) wins rather than {(⌣́}⌣).

Moreover, as one would hope, the mirror images of these moraic trochee hierarchies generate *precisely* the iambic and unbounded systems of (16), *plus* versions of these systems with right extrametricality. All these are attested. It must however be noted that for the LR iambic systems with extrametricality (rare: Hixkaryana and the much more complicated Asheninca), these constraints do not suffice to resolve the foot placement tie between, e.g., $(\smile\acute{\smile})(\smile\acute{\smile})\smile\smile$, *$(\smile\acute{\smile})\smile(\smile\acute{\smile})\smile$, and *$\smile(\smile\acute{\smile})(\smile\acute{\smile})\smile$, each of which has just one lapse.

The third and final case—syllabic trochees—is at first blush more difficult. If we allow STRESSALL-driven systems (see the end of §7 above for alternatives), syllabic trochees appear to be *parametrically* different from moraic ones. To obtain them from (33)–(34), while blocking unattested systems, three changes are necessary. First, ANTILAPSE(σ) replaces ANTILAPSE(μ), as in §6. Second, the quantity-sensitive ADOMEXCLUDE must vanish from the hierarchy (or stay below ADOMINCLUDE). Third, SPREAD-`x` must appear at the top of the hierarchy (above STRESSALL and ADOMINCLUDE).[23]

The resulting hierarchies do generate exactly RL syllabic trochees with and without extrametricality, LR syllabic trochees, and systems without secondary stress contrasts. But why should the above three changes be triggered by a single parameter? Why are there no mixed systems, that combine, say, ANTILAPSE(σ) with ADOMEXCLUDE? Or more descriptively: why do several trochaic languages (such as Pintupi; Hayes (1995, 102) lists others) behave in all *metrical* respects as if all syllables were light, but show quantity-sensitivity *elsewhere* in the grammar?

I suggest, tentatively, that the difference lies not in the metrical theory but in the moraification theory—that is, in a subhierarchy of syllable structure constraints universally ranked above (33). The idea is that *all* languages use exactly the constraints in (33), but that some languages happen to represent heavy syllables not as in Zec's (1988) (35a) but as in (35b).[24] The less common (35b) languages look like Pintupi if trochaic, but like ordinary iambic languages if iambic.

(35) a. **mora-chaining language**

$$\begin{array}{lccccccl} [& & & \sigma & & & &] \\ [& & \mu_s & &] & & & \\ & & & & [& \mu_w & &] \\ [& C &][& V &][& C & &] \end{array}$$

b. **mora-stacking language**

$$\begin{array}{lccccccl} [& & & \sigma & & & &] \\ [& & & \mu_s & & & &] \\ & & & & [& \mu_w & &] \\ [& C &][& V &][& C & &] \end{array}$$

In mora-stacking languages, the strong mora itself is spread over any weak mora; μ_s becomes coextensive with σ. Because stress must start and end on mora boundaries (FILL-`x`), trochaic stress (anchored at the left of the syllable) must cover the entire syllable. By contrast, iambic stress is not forced to be syllabic under (35b) any more than under (35a): it may cover either μ_w or μ_s.

[23] While SPREAD-`x` was also used in the ANTILAPSE-driven systems of §6, it was more comfortably assumed to appear in *all* systems (but ranked so low that it was inert except for syllabic trochees).

[24] Such a difference would not be hard to arrange formally. For example, it might be governed by the relative ranking of the clash constraint $\mu_s \perp \mu_w$, which favors (35a), and the spreading constraint $]_{\mu_s} \perp {}_{\mu_w}[$, which favors (35b).

We can now, first, dispense with SPREAD-`x`: all mora-stacking languages, both iambic and trochaic, already place stress precisely as an undominated SPREAD-`x` would require. Second, we can eliminate ANTILAPSE(σ), because mora-stacking languages respond to ANTILAPSE(μ) just as they would have responded to ANTILAPSE(σ): this is because ANTILAPSE(μ) targets mora boundaries ${}_{\mu}][_{\mu}$, and here these appear just at syllable boundaries. Finally, we must explain why mora-stacking languages would be insensitive to ADOMEXCLUDE, as if a string of heavy and light syllables contained no weak moras. Observe that for such a language, such a string at least is not *interrupted* by its weak moras. If we restate ADOMEXCLUDE as (36), it will have unchanged effect for mora-chaining languages but no effect for mora-stacking languages:

(36) ADOMEXCLUDE: $(ADom \text{ and }]_{\mu_s}) \rightarrow {}_{\mu_s}[$
"Within an alignment domain, every μ_s is immediately followed by another μ_s without interruption."

To summarize the whole system, the rather free primitive constraint rankings of (33)–(34) generate just the attested patterns for moraic trochees (plus unattested (32b)) in mora-chaining languages, and just the attested patterns for syllabic trochees in mora-stacking languages. The mirror-image constraints give just the attested patterns for iambic and unbounded languages, for both mora-chaining and mora-stacking languages. What appear to be parametric gaps or asymmetries, in a theory like Hayes (1995), emerge gracefully from the fact that the constraint in (27) and the syllable structures in (35) do *not* mirror.

10. Word-level stress and degenerate feet

Up till this point, we have been considering only one level of stress—what Liberman (1975) called **level-1 stress** on the **metrical grid**. The level-1 stress mark `x` falls on prosodic units that bear (at least) secondary stress. We now turn to the optimization of primary or **level-2** stress, which appears just on a word's main stressed syllable. In OTP, we represent level-2 stress as a further constituent type, `X`, which is universally constrained to span the width of a single syllable (say).

In Liberman (1975), the grid is taken to be inherently **scalar**: every `X` is supported by a `x`, as shown in (37). We may formulate this property in OTP via the constraint (38).

$$
(37)\quad (\grave{\sigma}\sigma)(\grave{\sigma}\sigma)(\acute{\sigma}\sigma) = \begin{array}{cccccc} & & & & \mathtt{X} & \\ \mathtt{x} & & \mathtt{x} & & \mathtt{x} & \\ \sigma & \sigma & \sigma & \sigma & \sigma & \sigma \end{array}
$$

(38) CONTINUOUSCOLUMN: $\mathtt{X} \rightarrow \mathtt{x}$.

Prince (1983) proposes a two-step process: first, secondary stresses are assigned metrically, and second, an **End Rule** strengthens the leftmost or rightmost of these into a primary stress. One may straighforwardly transport this account into a constraint-based framework as follows. The constraints described earlier in the paper fix the position of level-1 stress. Lower-ranked constraints then winnow the remaining candidates to those that optimize the position of level-2 stress.

We will need another universal constituent type to implement this End Rule: call it a **X-domain** (*XDom*). (New OTP constituents should not be invented lightly; this one is justified by the universality of the phenomenon.) Primary stress appears at the left edges of X-domains and nowhere else, owing to undominated constraints (39a). Just as the left edge of *XDom* corresponds precisely to primary stress, the right edge of an *XDom* corresponds precisely to the end of a word, owing to undominated (39b). Since each prosodic word has exactly one $]_{PrWd}$, it follows that each word will have exactly one *XDom* and one X. This is the principle of **culminativity**.

(39) a. $_{XDom}[\ \rightarrow\ \mathtt{X}[\quad,\quad \mathtt{X}[\ \rightarrow\ _{XDom}[$
b. $]_{XDom}\ \rightarrow\ ]_{PrWd}\quad,\quad]_{PrWd}\ \rightarrow\ ]_{XDom}$

I propose that the realization of the End Rule depends on the relative ranking of three violable constraints, two of which are converses of each other:

(40) a. SHORT-*XDom*: $XDom\ \perp\ \sigma$
“A word’s X-domain should contain as few syllables as possible, so that X (at the left edge of *XDom*) falls as far right as possible.”
b. *XDom*-ALL-x: $\mathtt{x}\ \rightarrow\ XDom$
“A word’s X-domain should cover all secondary stresses in the word.”
c. *XDom*-SOME-x: $XDom\ \rightarrow\ \mathtt{x}$ (alternatively, $]_{XDom}\ \rightarrow\ ]_{\mathtt{x}}$)
“A word’s X-domain should cover at least one secondary stress.”

The six possible rankings of these constraints yield just three patterns:

(41) a. SHORT-*XDom* is ranked highest: The *XDom* remains as short as possible—namely, on the final syllable alone. Primary stress therefore prefers to be word-final. This case is further discussed below.
b. *XDom*-ALL-x $\gg$ SHORT-*XDom*: The *XDom* stretches leftward to cover all secondary stresses, yielding End Rule Left. If there are no secondary stresses,[25] then stress remains final. Thus we have an “opposite-side default” version of End Rule Left (Prince 1985), as in Kwakw’ala. ($\smile\,[\acute{-}\smile\smile\grave{-}\smile]_{XDom}$, $\smile\smile\smile\smile\smile\,[\acute{\smile}]_{XDom}$)
c. SHORT-*XDom* $\gg$ *XDom*-ALL-x but *XDom*-SOME-x $\gg$ SHORT-*XDom*: The *XDom* stretches leftward to cover just the rightmost secondary stress, yielding End Rule Right. If higher-ranked constraints allow no secondary stresses, then *XDom*-SOME-x cannot be satisfied and stress again remains final; so we have a “same-side default” version of End Rule Right, as in Aguacatec. ($\smile\grave{-}\smile\smile\,[\acute{-}\smile]_{XDom}$, $\smile\smile\smile\smile\smile\,[\acute{\smile}]_{XDom}$)

[25] As may happen in unbounded stress systems (16c) when no heavy syllables are present, or in systems with no secondary stress constrast, as discussed at the start of §7.

To obtain other logically possible systems, simply replace the *XDom*-edge constraints in (39) with their mirror images. This yields, respectively, regular initial primary stress, End Rule Right with opposite-side default, and End Rule Left with same-side-default.[26]

Not only does this approach work for assigning primary stress in standard bounded and unbounded systems like those in (16), it also adapts well to more complex cases. Kelkar's (1968) Hindi is a variant of (41c) where primary stress assignment recognizes not two but three levels of prominence. These levels are defined by syllable weight ($\smile, -, =$) rather than secondary stress. Primary stress falls on one of the most prominent syllables; in the event of a tie, the rightmost nonfinal such syllable is chosen. To obtain this variation, simply replace highest-ranked *XDom*-SOME-`x` in (41c) with a prominence subhierarchy that is sensitive to *edges*, and a weak constraint against final primary stress, to obtain:

(42) $_{XDom}[\rightarrow {}_{=}[\;\gg\; {}_{XDom}[\rightarrow {}_{-}[\;\gg\; {}_{XDom}[\rightarrow {}_{\smile}[$
$\gg\;]_{\mathtt{X}} \perp]_{PrWd} \;\gg$ SHORT-*XDom* $\gg$ *XDom*-ALL-`x`

For a complex case involving bounded rather than unbounded systems, consider cases of foot extrametricality (Hayes 1995, 105–108) as found in several Arabic dialects. Here a word-final foot is ignored by End Rule Right. The simplest solution posits (41c) plus a primitive constraint $XDom \rightarrow]_F$, which requires the `X`-domain to stretch far enough left that its interior crosses a foot boundary. As for syllables, no extrametrical material need be explicitly marked. The solution correctly predicts that the rightmost foot will *not* be ignored if is not *word*-final (e.g., if it is followed by a stray syllable or even an extrasyllabic consonant, as in Arabic dialects and Stoney Dakota: optimal $[(\acute{\smile}\smile)(\grave{-})]_{XDom}$ and $(\grave{\smile}\smile)[(\acute{-})C]_{XDom}$).

Let us now turn to the ranking (41a), and assume the mirror images of (39). The primary-stress constraint SHORT-*XDom* would like initial stress here, but the constraints that assign secondary stress may have other plans. Hayes (1995, 116–118) provides a helpful example: moraic trochees (23) will strongly disfavor secondary stress on the first syllable of $\smile -$. If the first syllable is stressed, as (41a) wants, then the system cannot stress the second syllable without violating undominated BRANCH, or leave it unstressed without violating ANTILAPSE.

If primary stress wins this conflict (SHORT-*XDom* $\gg$ ANTILAPSE), then we have what Hayes calls **top-down stressing**: Old English $[(\acute{\smile}]-)$ is the optimal candidate, where [ ] denotes the *XDom*. Here SHORT-*XDom* and CONTINUOUS-COLUMN conspire to allow only candidates with initial secondary stress, and then BRANCH prefers the lapsed form $(\grave{\smile}-)$ to $(\grave{\smile})(\grave{-})$. But if secondary stress wins the conflict (ANTILAPSE $\gg$ SHORT-*XDom*), then we have Hayes's **bottom-up stressing**: Malayalam $[\smile(\acute{-})]$. Here the *XDom* has been forced to cover both

[26]Unfortunately, on this account, to relate Eastern Cheremis (End Rule Right, opposite-side) to Western Cheremis (End Rule Right, same side) requires both a mirroring and a reranking.

syllables, in order to place X upon a x as CONTINUOUSCOLUMN (38) requires.

(43) a. CONTCOLUMN, SHORT-*XDom* $\gg$ ANTILAPSE: top-down stressing
b. CONTCOLUMN, ANTILAPSE $\gg$ SHORT-*XDom*: bottom-up stressing
c. ANTILAPSE, SHORT-*XDom* $\gg$ CONTCOLUMN: "degenerate feet"

a.	b.	c.
X	X	X
x	x	x
($\smile$ —)	$\smile$ (—)	$\smile$ (—)
Old English	Malayalam	Cahuilla

There is, however, a third option, shown in (43c) and attested in Cahuilla. I will suggest that so-called degenerate feet can be analyzed via violations of CONTINUOUSCOLUMN—an apparently rigid constraint that like the prosodic hierarchy may actually be violable (Selkirk 1994, Everett 1996).

Languages such as Auca (syllabic trochees) apparently allow degenerate feet at word edge: $(\grave{\sigma}\sigma)(\acute{\sigma}\sigma)$, $(\grave{\sigma}\sigma)(\grave{\sigma}\sigma)(\acute{\sigma})$. One analysis is that the language simply fits in another stress mark if it can: e.g., it is STRESSALL-driven, and BRANCH is replaced with a less restrictive constraint ANTICLASH, $]_{\mathtt{x}} \perp {}_{\mathtt{x}}[$.[27] However, word-edge degenerate feet sometimes appear even in clash positions, as in Cahuilla $(\acute{\smile})(\grave{-})(\grave{\smile}\smile)$. So we need a more complete account of degeneracy.

Hayes (1995) makes the interesting proposal that some languages disallow degenerate feet entirely (**strong prohibition**), while others, like Auca and Cahuilla, allow them just if they bear primary stress X (**weak prohibition**). For example, Cahuilla and Old English are both LR moraic languages with obligatory initial stress (presumably due to ${}_{PrWd}[\rightarrow {}_{\mathtt{X}}[$). However, Cahuilla allows degenerate $(\acute{\smile})(\grave{-})\cdots$ (weak prohibition) where Old English apparently requires the awkward but non-degenerate trochee $(\acute{\smile}-)\cdots$ (strong prohibition).

We may reformulate Hayes's proposal as follows. Degenerate feet *never* exist (BRANCH is inviolable); in the weak-prohibition languages, primary stress X simply *does not project a foot*. After all, the stress-to-foot constraints in (10b), FILL-x, mention only x. Thus, Cahuilla is really $\acute{\smile}(\grave{-})\cdots$, which gives the appearance of a degenerate foot but in truth does not violate BRANCH. The strong prohibition in languages like Old English results from the CONTINOUSCOLUMN constraint above. This makes primary stress X project a (phonetically redundant) secondary stress mark x, which in turn requires a foot via FILL-x. Then $(\acute{\smile}-)$ is the only way to make this foot satisfy BRANCH. The insight is that strong-prohibition languages allow the placement of primary stress to affect the assigment of feet or

[27] A variation on this theme is to allow the last foot to overhang the edge of the word –an event known as **catalexis** (Kiparsky 1991, Green 1995, Kager 1995):

(i) $\acute{\sigma}\sigma\acute{\sigma}\sigma\acute{\sigma}\sigma\acute{\sigma}$ with trochees and catalexis.

```
[  x  ]     [  x  ]     [  x  ]
[     F     [     F     [     F      ]
[  σ  [  σ  [  σ  [  σ  [  σ  ]
```

secondary stress. Such an effect is possible just if some constraint that relates `X` to `x` such as CONTINUOUSCOLUMN, is ranked highly.

11. Conclusions

We have now considered a wide range of stress phenomena that are predicted by a single coherent system: Hayesian foot form, quantity sensitivity, unbounded stress, simple word-initial and word-final stress, iambic lengthening, directionality of footing, syllable (and foot) extrametricality, degenerate feet, and word-level stress, including prominence-based systems. (I have not addressed ternary rhythm, Trochaic Shortening, or the residue from Alignment.)

The metrical part of the account rests on the following intuitions: (a) iambs are special because they can lengthen their strong ends in a way recognized by syllable structure; (b) directionality of footing is really the result of local lapse avoidance; (c) any lapses are forced by a (localist) generalization of right extrametricality; (d) although degenerate feet are absolutely banned, primary stress does not require a foot in all languages. An interesting prediction of (b) and (c) is that left-to-right trochees should be incompatible with extrametricality. This prediction is robustly confirmed in Hayes.

The work is of interest for several reasons. For readers who are interested in comparing Optimality Theory with derivational theories, it is useful to know that OT can provide an interesting and rather accurate cross-linguistic typology of a complex phenomenon, and that the typology is in fact quite different in spirit from a careful derivational typology of the same data (Hayes 1995).

For readers who are concerned about the potentially unlimited power of OT mechanisms, it is a welcome and perhaps surprising result that these complex data can be modeled comfortably with the extremely simple, local, and independently motivated "primitive constraints" of *OTP* (§3). Indeed, the primitive constraints appear to have provided building blocks of the correct granularity, in that the ones used here can—and must—be reranked quite freely to get just the desired systems. This result appears to be technically sound, in that the very large tableaux resulting from these rerankings have all been checked thoroughly by computer.

Finally, readers who are primarily interested in stress systems may find the typology itself to be an improvement on previous work. §1 reviewed several paradigmatic gaps involving foot form and iterativity, which Hayes (1985, 1995) discussed in his groundbreaking synthesis, and which have persisted as gaps in recent OT accounts. The present work—constrained by the restricted OTP framework—was forced to construct a different paradigm. The happy result, as previewed in §1, is apparently to boil down all the apparent gaps to two uncontroversial stipulations: that syllable structure is asymmetric, and that extrametricality is asymmetric.

References

Akinlabi, Akinbiyi. 1993. Underspecification and the phonology of Yoruba /r/. *LI* **24**:1, 139–160.

Alderete, John. 1995. Faithfulness to prosodic heads. Handout, Conference on the Derivational Residue in Phonology, Tilburg University. ROA-93h, Rutgers Optimality Archive, `http://ruccs.rutgers.edu/roa.html`.

Buckley, Eugene. 1991. Persistent and cumulative extrametricality in Kashaya. Ms., University of California at Berkeley.

Cohn, Abigail, & John McCarthy. 1994. Alignment and Parallelism in Indonesian Phonology. ROA-25, Rutgers Optimality Archive, `http://ruccs.rutgers.edu/roa.html`.

Cole, Jennifer, & Charles Kisseberth. 1994. An optimal domains theory of harmony. *Studies in the Linguistic Sciences* **24**: 2.

Clements, G. N. 1985. The problem of transfer in nonlinear morphology. Cornell Working Papers, Cornell University, Ithaca, NY, Fall.

Crowhurst, Megan. 1991. Demorification in Tübatulabal: evidence from initial reduplication and stress. *NELS* **21**, 49–63.

Eisner, Jason. 1997a. What constraints should OT allow? Handout for talk at LSA, Chicago. Rutgers Optimality Archive, `http://ruccs.rutgers.edu/roa.html`.

Eisner, Jason. 1997b. Efficient generation in primitive Optimality Theory. Proceedings of the 35th Annual Meeting of the ACL (joint with the 8th Conference of the EACL), Madrid, July.

Everett, Daniel. 1996. Syllable integrity. Ms., University of Pittsburgh. ROA-163, Rutgers Optimality Archive, `http://ruccs.rutgers.edu/roa.html`.

Goldsmith, John. 1976. *Autosegmental Phonology.* Cambridge, Mass: MIT Ph.D. dissertation. New York: Garland Press, 1979.

Green, Thomas. 1995. The stress window in Pirahã: A reanalysis of rhythm in optimality theory. Ms., Massachusetts Institute of Technology (January). ROA-45, Rutgers Optimality Archive, `http://ruccs.rutgers.edu/roa.html`.

——— & Michael Kenstowicz. 1995. The Lapse constraint. Ms., Massachusetts Institute of Technology (June). ROA-101, Rutgers Optimality Archive, `http://ruccs.rutgers.edu/roa.html`.

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

Hayes, Bruce. 1985. Iambic and trochaic rhythm in stress rules. *BLS* **11**, 429–446.

———. 1995. *Metrical Stress Theory: Principles and Case Studies.* University of Chicago Press.

Hung, Henrietta. 1994. *The Rhythmic and Prosodic Organization of Edge Constituents.* Ph.D. thesis, Brandeis University.

Hyman, Larry. 1977. On the nature of linguistic stress. In Larry Hyman, ed., *Studies in Stress and Accent*, 37–82. Southern California Papers in Linguistics **4**, Dept. of Linguistics, Univ. of Southern California, Los Angeles.

Kager, René. 1989. *A Metrical Theory of Stress and Destressing in English and Dutch.* Linguistic Models **14**. Dordrect: Foris.

———. 1992. Shapes of the generalized trochee. *WCCFL* **11**.

———. 1993. Alternatives to the Iambic-Trochaic Law. *LI* **11**, 381–432.

———. 1995. Stem Disyllabicity in Guugu Yimidhirr. Ms., Utrecht University. ROA-70, Rutgers Optimality Archive, `http://ruccs.rutgers.edu/roa.html`.

Kelkar, Ashok. 1968. *Studies in Hindi-Urdu I: Introduction and Word Phonology.* Deccan College, Poona.

Kiparsky, Paul. 1991. Catalexis. Ms., Stanford University and Wissenschaftskolleg zu Berlin.

Liberman, Mark. 1975. *The intonational system of English.* Ph.D. dissertation, MIT. Distributed by Indiana University Linguistics Club.

Lombardi, Linda. 1995. Positional faithfulness and the phonology of voicing in Optimality Theory. Ms., University of Maryland, at College Park.

Mascaró, Joan. 1976. *Catalan phonology and the phonological cycle.* Ph.D. dissertation, MIT. Distributed by Indiana University Linguistics Club.

McCarthy, John. 1995. Faithfulness in prosodic morphology and phonology: Rotuman revisited. Ms., University of Massachusetts, Amherst. ROA-110, Rutgers Optimality Archive, `http://ruccs.rutgers.edu/roa.html`.

McCarthy, John, & Alan Prince. 1986. Prosodic morphology. Ms., Brandeis University.

———. 1993. Generalized alignment. *Yearbook of Morphology*, ed. Geert Booij & Jaap van Marle, 79–153. Kluwer.

———. 1995. Faithfulness and reduplicative identity. In Jill Beckman et al., eds., Papers in Optimality Theory. UMass, Amherst: GLSA. 259–384.

Prince, Alan. 1976. Applying stress. Ms., University of Massachusetts, Amherst.

———. 1983. Relating to the Grid. *LI* **14**, 19–100.

———. 1985. Improving tree theory. *BLS* **11**:471–90.

———. 1990. Quantitative consequences of rhythmic organization. **CLS 26**, vol. 2, 355–98.

——— & Paul Smolensky. 1993. *Optimality Theory: Constraint Interaction in Generative Grammar.* Technical Reports of the Rutgers University Center for Cognitive Science.

Selkirk, Elisabeth. 1980a. Prosodic domains in phonology: Sanskrit revisited. In Mark Aranoff and Mary-Louise Kean, eds., *Juncture*, 107–129. Saratoga, CA: Anna Libri.

———. 1980b. The role of prosodic categories in English word stress. *LI* **11**, 563–605.

———. 1984. *Phonology and Syntax: The Relation between Sound and Structure.* Cambridge, MA: MIT Press.

———. 1994. Elisabeth Selkirk, The prosodic structure of function words. In Jill N. Beckman, Laura Walsh Dickey, and Suzanne Urbanczyk, eds., *U. Mass. Occasional Papers 18: Papers in Optimality Theory*, 439–470.

Stanley, R. 1967. Redundancy rules in phonology. *Language* **43**:393–436.

Steriade, Donca. 1995. Positional neutralization. Ms., UCLA.

Zec, Draga. 1988. *Sonority Constraints on Prosodic Structure.* Ph.D. dissertation, Stanford University.

Dept. of Computer and Information Science
200 S. 33rd St.
Philadelphia, PA 19104
USA

jeisner@linc.cis.upenn.edu