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5. Skeletal Positions and Moras

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0 Introduction

Perhaps the major development in post-*Sound Patterns of English* generative phonology has been the emergence of a framework in which various aspects of phonological representation (similar to those called, in other frameworks, prosodies [Firth 1957] or long components [Harris 1944]) are factored out of individual segments and placed on independent tiers. Among the various tiers that have been proposed is a *skeletal tier* or *timing tier*, which, in its original incarnation, served a number of different functions: to mark off segments, to represent segment length, and to describe the shape of grammatical formatives. The elements on this tier were conceived of, in most theories, as part of lexical representation, serving as the units on which higher prosodic structure was built. More recently, however, the task of enumerating segments has largely been taken over by *root nodes*, which serve, in a theory that allows intrasegmental hierarchical structure, as anchors for the distinctive features which define a segment. Morphological templates, on the other hand, have been described in terms of higher prosodic units, including *moras*, which serve as indicators of syllable weight. And segment length has been described as a function of mapping either to two root nodes or to two prosodic nodes.

The overlap between the functions of the skeletal, root, and moraic tiers leaves the precise nature of the structure mediating between syllable nodes, on the one hand, and feature specifications, on the other, as one of the major questions in phonological theory. That question is the topic of this chapter. The organization of the chapter is roughly historical, beginning in section 1 with a review of the sorts of arguments that have been proposed for a skeletal tier, the content and functions of this tier (in 1.4), and the extent to which these functions have been subsumed by the root node and by higher prosodic units, including the mora (in 1.5). Section 2 examines the evidence both for and against a moraic tier: 2.1 reviews various proposals for the assignment of moraic structure, 2.2 presents arguments for the moraic tier rather than the skeletal tier, as well as problem cases, and 2.3 considers the relationship of moras and syllables.

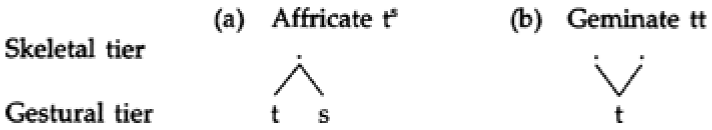
1 Arguments for a Skeletal Tier

A skeletal tier provides a representation of the length and arrangement of segments in a word, independent of particular articulatory gestures. Early arguments for this level of representation draw explicit parallels between phenomena described by means of a skeletal tier and what at the time appeared to be more obviously autosegmental phenomena (see Goldsmith 1976a, 1990). Thus, autosegmental analyses of long segments and affricates in terms of many-to-one mappings are analogous to similar analyses of tone spreading and contour tones; the postulation of prosodic shape as a morphological entity recalls the role of stable tone melodies as independent morphological units; and arguments for empty skeletal slots parallel arguments for floating tones.

1.1 Many-to-one Mappings

Affricates, prenasalized stops, clicks, and other complex segments involve more than one place or manner of articulation, but frequently share the distributional properties of single segments. Conversely, long vowels and geminate consonants, which commonly involve a single gestural component, may behave as equivalent to sequences of two discrete gestural units for various processes. The lack of isomorphism between segmental and gestural structure can be represented by many-to-one mappings between the skeletal tier and what I will call the *featural* or gestural tiers (also called the *melodic, segmental*, or *articulatory* tiers). Thus, for example, a possible two-tiered representation of an affricate t^s is as in (1a), with two sets of articulatory specifications mapped to a single skeletal position. A geminate *tt*, in contrast, can be represented as in (1b), with a single set of articulatory features mapped to two skeletal positions:

(1)



Leaving aside for the moment the content of these tiers, the representation in (1a) is intended to indicate that the affricate patterns with clearly monosegmental units: for example, Japanese t^s is the only sequence of obstruent gestures to occur in syllable onset and the only such sequence not to trigger epenthesis in borrowed words, as in *furuutsu* "fruits". Similarly, prenasalized stops may occur in syllable onsets, in violation of sonority sequencing generalizations, and in languages where bisegmental onsets are ruled out (see the Bakwiri example below). The representations in (1) open the possibility that affricates and geminates may pattern with single segments for some phonological processes, with segment sequences for others. While the evidence for the dual patterning of affricates is somewhat ambiguous (see section 1.5.2 for discussion), this sort of behavior is well established for geminates and long vowels: typically, long segments add to syllable weight, but tend to resist separation by rules of epenthesis, and fail to undergo rules whose structural descriptions are met by only one portion of the geminate structure – properties termed, respectively, *integrity* and *inalterability* by Kenstowicz and Pyle (see chapter 8, this volume). A representation of long segments as in (1b) ensures that rules that scan the skeletal tier will see these segments as two units, while rules that operate exclusively on the gestural tiers will see them as single elements. The integrity and inalterability of geminates can be made to follow from general conditions on the interpretation of linked structures by phonological rules (ibid.).

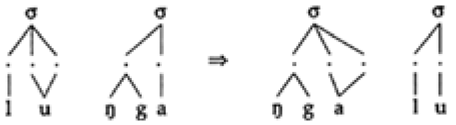
An example of the usefulness of the separation of length from gesture comes from Bakwiri, a Bantu language, whose speakers play a language game in which the segmental material of two syllables within a word is transposed (Hombert 1986, and also chapter 23, this volume):

(2) Bakwiri

	Normal form	Language game form	
(a)	mɔkɔ	kɔmɔ	"plantain"
(b)	kóndì	ndíkò	"rice"
(c)	lùùŋgá	ŋgààlú	"stomach"
(d)	zééyá	yáázé	"burn"

As (2c, d) illustrate, length is preserved in its original position despite the reversal of segmental material (as in other languages; see Conklin 1959, McCarthy 1982). As McCarthy (1982) points out, positing independent skeletal and articulatory tiers makes this sort of phenomenon easy to account for: the skeletal tier is left intact, while the elements on the articulatory tier(s) are transposed:

(3)



Tone also maintains its original position, suggesting that tonal melodies are anchored to the skeletal rather than to the gestural tiers. It is significant as well that after transposition, both components of the prenasalized stop are still mapped to a single skeletal slot, forcing the transposed *a* to spread to fill the second and third slots of the initial syllable.

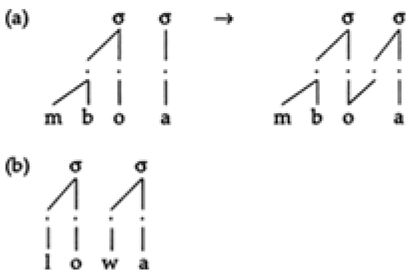
The language game suggests the need for another type of many-to-one mapping. Certain Bakwiri forms are peculiar in failing to undergo reversal. These nonreversing forms all contain a non-low vowel followed by a homorganic glide, as in (4a) – although, as (4b) shows, some phonetically similar forms do reverse:

(4)

	Language form	Game form	
(a)	mbówà	mbówà	"village"
(b)	lówá	wáló	"excerment"

Hombert (1986) argues that forms like (4b) have an underlying medial glide, while in (4a) the glide is inserted to break the hiatus between two vowels. A framework allowing multiple linkings can represent the contrast between (4a) and (4b) as follows, with the vowel of the (a) form linked to positions in both syllables:

(5)



The derivation in (5a) shows the vowel features spreading to provide an onset for the second syllable. A new skeletal slot has been added to the post-vowel spreading representation of (5a); this is necessitated by the assumption that all gestural features are supported by a skeletal slot. On this account, the language game reversal of the featural material linked to the first and second syllables is stymied when faced with the *o* of (5a), which shares simultaneous membership in both syllables. While the doubly-linked vowel is not a long segment in the usual sense, it is similar to long vowels and geminates in being linked to two positions: in this case, the nucleus of the first syllable and the onset of the second (where it is interpreted as a glide). As a doubly-linked segment, the *ow* sequence should exhibit the characteristic integrity of conventional geminates.[1]

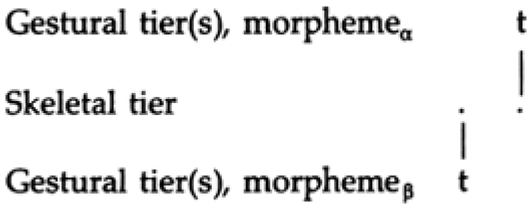
1.1.1 Contrasts in Mapping

The two-tiered representation of segment structure and length allows the possibility that languages may contrast in their mapping between gestural and skeletal tiers. The *ts* sequence in English *fruits*, for example, is presumably analyzed as two independent consonants, unlike the corresponding sequence in Japanese *furuutsu*. Such contrasts in mapping have been argued to play a role within the same language; for example, Clements and Keyser (1983) argue that Polish *czy* "whether" and *trzy* "three" (both phonetically *tši*) are distinguished only by the mapping of the initial sequence *tš* to one versus two skeletal slots. The two-tiered representation of length also in principle allows a similar one-to-one versus one-to-many contrast in geminates:

(6)

However, unlike the mapping of two gestural units to separate skeletal slots proposed for Polish bisegmental *tš*, the mapping in (6b) involves two identical gestural units. McCarthy (1981) has proposed that this sort of representation is ruled out by universal constraints; if the Obligatory Contour Principle (OCP), criginally formulated as a constraint prohibiting adjacent identical tones, is extended to prohibit adjacent identical elements on the gestural tier, representations like (6b) will be impossible,[2] assuming that the tiers on which the *t* gestures are specified occupy the same plane. McCarthy does propose, for independent reasons, that each morpheme occupies its own plane, which allows a representation for heteromorphemic *t* + *t* as in (7), in which the tiers specified for *t* are arranged on separate planes:

(7)



Identical segments rendered adjacent by morpheme concatenation (often called *fake* or *apparent* geminates), being immune to the OCP, presumably have the one-to-one structure illustrated in (7), while "true" (morpheme-internal) geminates have the structure of (6a). Thus, universal constraints impose contrasting representations of tauto- and heteromorphemic geminates. This contrast leads us to expect differences in behavior, an expectation that is confirmed by the generalization that the properties of integrity and inalterability typically hold only of tautomorphemic geminates (chapter 8, this volume; and Guerssel 1977; Hayes 1986; Schein and Steriade 1986).[3]

The segregation of separate morphemes onto separate planes raises the possibility of so-called long-distance geminates – a single gestural unit mapped to two skeletal positions that are nonadjacent on the surface. Convincing arguments for such structures have been offered in conjunction with arguments for the role of the skeletal tier as an independent morphological unit.

1.2 Skeletal Shape as a Morphological Element

The work that was most influential in establishing the independence of a skeletal tier was McCarthy's (1981) analysis of Arabic morphology. McCarthy argued that the Semitic root and pattern system of morphology, in which consonantal sequences appear in a number of related words of various shapes, could be best described as the mapping of consonantal roots to skeletal templates, each template defining the appropriate shape for a particular morphological category. Thus, for example, the same root appears in a number of stems sharing a semantic field:

(8)

(a) katab "write" (perfective)
(b) kattab "teach/cause to write" (perfective)
(c) kaatib "writing"

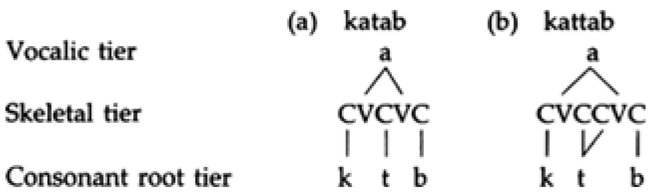
Morphological categories are marked by particular shapes and vocalisms, as revealed by comparison of corresponding forms with a different root:

(9)

(a) ħamal "carry" (perfective)
(b) ħammal "make carry" (perfective)
(c) ħaamil "carrying"

In McCarthy's analysis, consonantal roots, vowel melodies, and skeletal templates are all considered separate morphemes. Consonants and vowels are linked by rules of association to the skeletal template, which serves as a core anchoring the other segments and establishing the linear order of segments on discrete planes. In the face of contrasts like *kattab* versus *kaatib*, McCarthy proposed that each template position be specified as either C or V, with consonantal gestures linking only to C slots and vowel gestures to V slots. We can illustrate this approach by considering two forms that differ only in the number of their skeletal slots:

(10)



The mechanisms for mapping between tiers were argued to be the same as those employed in tonal mappings. The unmarked case involves left-to-right association. The rightmost element is spread when the number of slots on the skeletal tier exceeds the number of segments available for association – although language-specific rules may produce other spreading patterns, as in (10b).[4] Perhaps the most convincing evidence for some form of templatic tier in morphology is the lengths to which languages go to realize skeletal template positions. While articulatory material may be lost under association (in Arabic, the final consonant of the borrowed word *maǰnaţiiš* "magnetic" is lost when the root is mapped to the four-consonant CVCCVC template, yielding *maǰnaţiiš* "to magnetize" [McCarthy 1981]),[5] languages tend to ensure that skeletal slots are filled, even in the face of limited articulatory resources (see the Template Satisfaction Condition of McCarthy and Prince 1986). The spread of segmental material to fill adjacent empty positions is illustrated in (10b) *kattab*, where spread creates a geminate consonant. The segregation of vowels and consonants on different tiers implies that gestural material may spread to nonadjacent positions as well, without crossing association lines. Such long-distance spreading is motivated by the need to fill out the template; thus, McCarthy (1981) argues, Arabic stems like *samam* "poison" (perfective) are actually derived by mapping a biconsonantal root *sm* to the CVCVC template that produces katab (10a), with association of the second consonant to two template positions. The arguments for long-distance geminates are compelling. First, Arabic otherwise forbids two consonants within a root with identical place of articulation, so if the root were *smm* (in violation of the OCP), the constraint would have to allow homorganic root consonants only if they are identical in all features, but not in other cases. Second, identical consonants are found only in the two final positions (Arabic has no verbs of the type **sasam*), as expected if biconsonantal roots are mapped to skeleta from left to right. Third, the Ethiopian Semitic language Chaha provides a dramatic demonstration of the segmental unity of two identical root consonants, as McCarthy (1983) demonstrates. In this language, the feminine marker on CVCVC imperative verbs is realized as palatalization of the stem-final consonants:

(11) Chaha

	Masculine	Feminine	
(a)	nəmæd	nəmæd^y	"love"
(b)	nəqəṭ	nəqəṭ^y	"kick"
(c)	wəṭæq	wəṭæq^y	"fall"
(d)	bætət	bæt^{y}ət^y	"be wide"
(e)	nəqəq	nəq^{y}əq^y	"take apart"

As (11d, e) illustrate, when the last two consonants are identical, both are palatalized, precisely as expected if the identical consonants represent the reflex of a single articulatory unit mapped to two skeletal slots.

Spreading is, furthermore, not the only tactic used to realize template shape.

For example, the Ethiopian Semitic language Amharic chooses the option of inserting a default segment, rather than spreading an existing segment, illustrated by the appearance of *t* in the final slot of certain templates (Broselow 1984). The Californian language Sierra Miwok, in which the basic roots mapped to templates include both consonants and vowels, provides both a default consonant, ?, and a default vowel which varies between high and mid central, here represented as ə (Broadbend 1964; Smith 1984). Again, appearance of the default segments is motivated by the necessity for realizing the full skeletal template:

(12) Sierra Miwok (from Smith 1984, no glosses)

	Root	Derived (CVCVC)	Derived (CVCVVC)
(a)	polaat	polat	polaat
(b)	peeki	peki?	pekii?
(c)	tiil	tilə?	tiləə?

While the initial arguments for skeleta as morphological entities were made from the root-and-pattern system of Semitic, the use of morphological skeleta was quickly extended both to non-Semitic languages (Archangeli 1983; McCarthy 1982; Halle and Vergnaud 1980, among others) and to other morphological phenomena, most notably reduplication. Since the allomorphs of reduplication have in common only their shape, taking their gestural color from the bases to which they are attached, reduplication can be analyzed as affixation of a skeleton to a stem, with the gestural material of the stem then copied and associated to the affixed skeleton (Marantz 1982). We will return to this phenomenon when considering the specification of the skeletal tier and the replacement of a skeletal tier by higher prosodic structure.

1.3 Empty Skeletal Slots

Root-and-pattern morphology and reduplication make use of empty slots to characterize morpheme shape; another possible function of empty slots is to serve as placeholders within lexical items. Thus, certain morphemes have been argued to contain, in addition to slots specified for both skeletal and gestural information, skeletal slots which are underlyingly empty, or which become empty in the course of the derivation through deletion of gestural material.[6] These empty slots may themselves remain unfilled, their presence serving only to block or trigger phonological rules, or they may be realized through spreading of neighboring segments. An example of the first sort of analysis is the familiar case of French *h-aspiré*. This involves words which, although phonetically vowel-initial, pattern with consonant-initial forms in triggering deletion of a preceding consonant in a liaison environment (*lez ami* "the friends" versus *le aš* "the axes") and in preventing deletion of a preceding vowel (*lami* "the friend", but *la aš* "the ax"). Clements and Keyser (1983) propose that a word like *aš* has in its underlying representation the skeleton CVC, with gestural material associated only with the second and third slots. Examples like the French case, in which the underlying empty slot is never filled in surface representation, are rare. Much more common are cases in which an empty slot is filled at some point in the derivation. This may be an underlyingly empty slot; in Tiberian Hebrew, for example, the definite determiner can be analyzed as containing a final empty skeletal slot, which generally triggers gemination of the consonant following it, though when this consonant is one of those that cannot geminate (such as ?), the vowel of the determiner lengthens instead (see Prince 1975 and Lowenstamm and Kaye 1986 for fuller discussion):

(13)

	Noun	Det + Noun	
(a)	bayit	habbayit	"house"
(b)	?iiš	haa?iiš	"man"

Perhaps the most familiar sort of empty slot, however, is that created when a segment is deleted in the course of the derivation. In the well-known phenomenon of *compensatory lengthening*, deleted segments appear to leave a "trace" which is filled by spread of another segment. For example, Ingria (1980) cites the case of Ancient Greek /*es+mi*/ "I am" which is realized, after deletion of the *s*, as *eemi* in one dialect, *emmi* in another (see Wetzels and Sezer 1986 for numerous examples). A likely candidate for the remaining trace is the skeletal slot. But in both the Tiberian Hebrew and the Greek cases, the empty position may be filled by either a consonant or a vowel, which raises the question of precisely how skeletal slots should be defined.

1.4 Content of the Skeletal Tier: C/V Slots versus X Slots

McCarthy's (1979, 1981) characterization of skeletal slots as specifications for the feature [syllabic] was adopted in numerous analyses (withe the occasional modification; for example, Yip's (1982) analysis of a Chinese secret language requires specification of some slots as glides). However, as use of the skeletal tier was extended to various phenomena, it soon became clear that the identification of skeletal slots with major class features was too restrictive. As the Tiberian Hebrew and Greek lengthening cases illustrate, certain slots seem not to discriminate between vowels and consonants as potential suppliers of articulatory material. This is particularly noticeable in compensatory lengthening, which frequently consists of deletion of a consonant followed by lengthening of a vowel. Furthermore, the same interchangeability of vowels and consonants can be found in templatic morphology. One much-discussed case in which a reduplicative affix can be realized by either vocalic or consonantal material comes from Mokilese (Levin 1983, 1985a):

(14)

(a)	wadek	*wad*wadek	"read"
(b)	poki	*pok*poki	"beat"
(c)	pa	*paa*pa	"weave"
(d)	andip	*and*andip	"spit"

In (14a, b) the prefix is CVC, and in (14c), where no second consonant is available, the prefix is CVV, where the third position is filled by spreading of the vowel. A similar pattern is found in Palauan (Finer 1986-87), with the interesting difference that the affix may be filled by a sequence of two different vowels rather than a single long vowel.[7] The flexibility in filling skeletal slots in Mokilese, however, goes beyond that in Palauan; as (14d) illustrates, the prefix has the shape VCC. Thus the forms in (14) can be described as a copy of the first three segments of the stem, regardless of syllabicity. To handle cases like these, Levin (1985a, p. 29) proposes removing major class specifications from skeletal slots, with each “intrinsically featureless” slot representing “a single timing unit.” On this view, timing slots are not meant to represent some actual durational value, since average durations vary widely according to such factors as segment position and articulation type; timing slots encode the durational difference between long and short segments, but otherwise serve largely as segment enumerators. Slots on the timing tier are represented formally by an X, so the Mokilese reduplicative prefix illustrated in (14) would consist of three X slots.

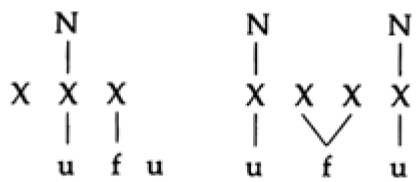
Reduplication does not, however, generally involve simply copying a specified number of segments from a base, as expected if reduplicative affixes simply specify a fixed number of positions. As Moravcsik (1978) points out in her survey of reduplication, a reduplication process that copies the first CV(C) of consonant-initial stems will normally copy just the first V(C) of vowel-initial stems:

(15) Agta Plural Reduplication

(a) takki *tak*takki “leg”
(b) uffu *uf*uffu “thigh”

Thus, where the C/V specification of skeletal slots was too specific, specification in terms of X slots alone is too general. Levin accounts for facts like these by reincorporating some syllabicity information into the template. The Agta prefix, for example, can be defined as consisting of three X slots, the second of which is specified as a syllable nucleus. As in C/V-based analyses, association from gestural tier to timing tier proceeds from left to right, and from gestures to timing slots. Therefore, an initial copied vowel will map to the nucleus slot, leaving the first slot blank:

(16)



In Levin's system, then, the skeletal tier contains only nonredundant information about syllabicity; predictable information is derived by syllabification rules. However, additional information concerning the syllabic structure of the template affix may also be required. For example, while the Mokilese prefix always fills three timing slots, these slots are not necessarily filled by copies of the first three segments of the base:

(17) Mokilese

(a) diar *dii*diar “find”
(b) alu *all*alu “walk”

In (17a, b), reduplication involves lengthening of the second copied segment, rather than simple one-to-one association (which would yield **diadiar*, **alualu*). Since both base forms in (17) have two vowels among their first three segments, and since in Mokilese each vowel must be a discrete syllable nucleus, these facts can be accounted for by imposing an additional restriction on the Mokilese XXX prefix: it must constitute a single syllable (Levin 1985, p. 36). However, the notion that a templatic morpheme like the Mokilese prefix may be defined in terms of its syllable structure invites a very different conception of templatic morphology than the purely skeletal representation, an alternative to which we shall now turn.

1.5 Alternatives to the Skeletal Tier

1.5.1 Prosodic Templates

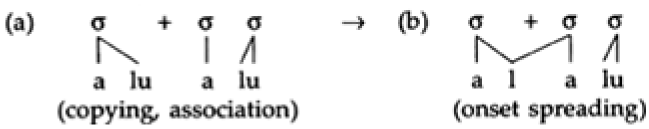
Once an affix is defined as a syllable, much of the information encoded in the skeletal tier (maximum number of segments, syllabicity of segments in various positions) is redundant, following from the syllable structure constraints of the language – inviting the conclusion that the skeletal tier may not be needed. One of the arguments offered in McCarthy and Prince's influential manuscript “Prosodic Morphology” (1986) for a syllabic rather than a skeletal representation of morphological templates concerns the reduplication pattern in Ilokano, in which the reduplicative affix may have the shape CVC, CCVC, CV, VC, as in (18).

(18) Ilokano
(a) ag-*bas*basa
(b) ag-*trab*trabaho
(c) ag-*da*dait
(d) ag-*ad*adal

McCarthy and Prince argue that the template to which the copied gestural material is mapped is defined simply as a syllable. The material that survives under copying is the maximum that a single syllable of the language can support. Thus, initial *tr* survives in (18b) because *tr* is a possible onset of the language, a generalization that would be obscured by merely providing another optional C or X slot in the template. The failure to copy the second vowel in (18c) also follows from the definition of the template as a syllable, since vowel sequences in this language, as in Mokilese, are bisyllabic. However, where in the analysis of Mokilese discussed above the template was defined as a sequence of slots as well as a single syllable, here syllable shape constitutes the sole definition of the template.

This approach can be extended to Mokilese as well. The generally trisegmental nature of the prefix is accounted for not by defining the prefix as both XXX and a single syllable, but rather by specifying this prefix as a heavy syllable.[8] The CVC/CVV alternation in prefix shape (illustrated by (14b) *pokpoki* and (14c) *paapa*) is motivated by this requirement. Forms like (14d) *andandip* and (17b) *allalu* are derived by associating as much of the copied material as possible to the reduplicative prefix. Since a syllable may be closed by no more than one consonant, only the first vowel and consonant of *andip* and *alu* will be copied, yielding **an-andip*, **al-alu*. The realization of the *d* and lengthening of the *l*, which in Levin's analysis resulted from the presence of a third timing slot in the prefix, is in McCarthy and Prince's analysis the effect of an independent rule that spreads a consonant to the onset position of a following vowel-initial syllable under certain morphological conditions:

(19)



Under the assumptions of this analysis, one should not expect to find a language identical to Mokilese in all relevant respects except that the reduplication of forms of words like *alu* yields forms like *aalalu*, where no onset filling analysis of vowel spread is available. Cases like this, where reduplication appears simply to copy a fixed number of segments, regardless of their prosodic properties, are hard to find. If alternative analyses of the sort suggested by McCarthy and Prince can be maintained for such cases, the motivation for an X-slot analysis of reduplication is seriously undermined.[9]

In fact, Prince's (1975) and Lowenstamm and Kaye's (1986) analyses of Tiberian Hebrew lengthening and Ingria's (1980) and Prince's (1984) analyses of compensatory lengthening in Latin and Greek also treat lengthening as an effect of mapping to terminal positions of a syllable, rather than as mapping to skeletal slots. But it was not until the circulation of McCarthy and Prince's (1986) manuscript that the analysis of shape-based phenomena in terms of prosodic structure was identified as a research program. In the prosodic morphology framework, the units of templatic morphology are defined not as slots on a skeletal or timing tier, but rather as units of prosodic structure which include, in addition to syllables, constituents both above the syllable (metrical feet) and below the syllable (moras). In section 2, we consider various arguments that higher prosodic structure may assume many of the functions originally assigned to the skeletal tier: encoding segment length and ambisyllabicity; providing a rationale for lengthening phenomena; making possible a direct representation of morpheme shape. Before considering the alternatives for representing morpheme shape and segment length, I return to one additional function originally delegated to the skeletal tier.

1.5.2 Root Nodes as Segment Delineators

The skeletal tier makes possible a monosegmental representation of elements with different and sometimes contrasting articulations. For example, the representation of the affricate t^s in (1a) shows two full sets of articulatory features, one defining *t* and the other *s*, mapped to a single skeletal slot. On this view, each set of features is an independent gestural unit on some level, and hence, once detached from the skeleton, an affricate should be indistinguishable from a bisegmental stop-fricative sequence. However, these units have not been shown to exhibit the same sort of independence evidenced by true single segments. For example, while segments may be reordered in language games that sever the connection between skeletal and gestural tiers, the separate portions of affricates or prenasalized stops have never been shown to reorder under similar conditions. Furthermore, phonological rules tend to treat the contrasting specifications within these segments as unordered (as Lombardi 1990 demonstrates for affricates and Sagey 1986 for clicks and other complex segments). And, as discussed in connection with Arabic morphology, while mapping of a single articulatory complex to multiple skeletal slots is quite common, the reverse is rare or unattested; neither, to my knowledge, have cases been found where the portions of an affricate split to associate to two different skeletal positions. These facts suggest that articulatorily complex segments have a connection below the skeletal level. The model of segment-internal structure generally referred to as *feature geometry* (see chapter 7, this volume) provides a means of representing articulatorily complex segments that does not rely on a skeleton. The guiding assumption is that features within a segment are arranged hierarchically, and are ultimately dependent on a single node, called a *root node*. A segment such as t^s would, on this account, consist of a single root node dominating a single specification for place but two specifications for continuancy. The root node in some accounts is simply an anchor for the features defining a segment, though McCarthy (1988) has proposed that the root node consists of the class features [consonantal, sonorant].[10] On either account, the root node appears to have usurped the function of the skeleton in describing complex segments. I return to the question of whether segment length and segment complexity are best described at the same level of representation in section 2.1.3, in the context of a closer look at content of the moraic tier.

2 Moras

The notion of mora, or weight unit, is a traditional one, recognized in virtually every school of linguistics. The concept arose from study of languages in which two adjacent segments in syllable rhyme may carry different pitches (for discussion of the phenomenon in Japanese, see McCawley 1968), or in which the position of stress, accent, or tone depends on an opposition between light (CV) syllables and heavy (CVV or CVC) syllables (see Newman 1972 for a valuable survey of languages making this distinction). Trubetzkoy ([1939] Baltaxe trans., 1969, p. 174) characterizes certain languages as mora counting:

> Classical Latin may be cited as a generally known example, where the accent …always occurred on the penultimate “mora” before the last syllable, that is, either on the penultimate syllable, if the latter was long, or on the antepenultimate, if the penultimate was short. A syllable with a final consonant was considered long. A long vowel was thus

comparable to two short vowels or to a "short vowel + consonant."

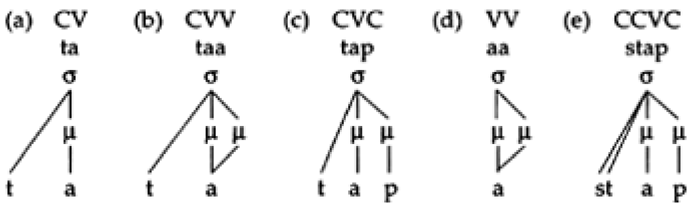
Mora count thus encodes both the opposition between heavy (bimoraic) and light (monomoraic) syllables, and the equivalence of various types of heavy syllables.

While many early generative accounts referred informally to moras, it was not until the 1980s that the mora was proposed as an explicit level of representation, and its use extended to account for many of the phenomena formerly described by means of the skeletal or timing tiers. Recent proponents of a moraic tier include Hyman (1985), who derives moras from units on a timing tier, Hock (1986), who suggests supplementing the skeletal tier with an autosegmental mora tier, and McCarthy and Prince (1986) and Hayes (1989), who advocate wholesale replacement of the skeletal tier by the mora tier. The arguments for the mora tier come from various domains; their essence is that shape-dependent processes can be seen as depending on syllable weight rather than on number of segments, and that the units necessary for the description of syllable weight are the same units motivated for the analysis of phenomena like stress, tone, and accent. Before considering these arguments in detail, I begin with an overview of various proposals for the representation of moraic structure.

2.1 Moraic Structure

For languages that treat all types of heavy syllables as equivalent, we can assume that each unit in the syllable rhyme – that is, the first vowel and all following material – contributes a mora. Since syllable onsets seem not to contribute to syllable weight (but see Everett and Everett 1984), they are assumed to have no moraic value. Thus, all syllables describable as C_0VV or C_0VC are equivalent in terms of their mora count. One possible representation of the weight of various syllable types is shown in (20), with μ representing a mora:

(20)

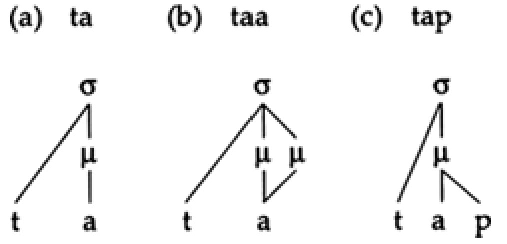


The wightlessness of onset units is represented in (20) by direct adjunction of onset segments to the syllable node, though the adjunction of onsets directly to the first mora is equally plausible (see sec. 2.1.2).

2.1.1 Structure of the Rhyme

All versions of moraic theory incorporate some possibility for variation in the moraic structure of syllable rhymes. Hayes (1989), for example, proposes that vowels are underlyingly associated with moras (short vowels with one mora, long vowels with two), while consonants generally receive their moraic value by language-specific rules: in a language where CVC and CVV are equivalent in weight (such as English, Latin, or Arabic), a rule Hayes calls *Weight-by-Position* assigns a mora to each consonant in coda position. Weight-by-Position is language-specific, failing to apply in languages that recognize only syllables with long vowels as heavy, treating CV and CVC syllables as equivalent; examples include Mongolian, Huasteco, and Lardil. Such languages simply adjoin the coda consonant either directly to the syllable node, or to the mora dominating the nuclear vowel, as shown below:

(21)



From this it follows that no language will treat CVV syllables as light but CVC syllables as heavy, since only syllables of the latter type can be represented as either mono- or bimoraic.

Languages may also identify only particular consonants as undergoing Weight-by-Position (see for example Hyman 1985). Zec (1988) argues that the choice of which consonants may be mora-bearing is constrained by sonority – consonants that may bear a mora are more sonorous than those which cannot. In Lithuanian and Kwakwala, for example, short-vowel syllables closed by a sonorant consonant behave as heavy, while those closed by an obstruent do not; therefore, only coda sonorants are assigned weight. The nonuniversality of Weight-by-Position provides an important part of the justification for a moraic representation, since if the set of mora-bearing segments were identical with the set of syllable rhyme segments in all languages, moraic structure would be simply derivable from syllable structure.

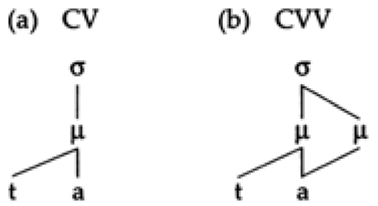
Hayes (1992) argues that languages may also contrast heavy and light CVC syllables that are segmentally identical (see also Kager 1989). The evidence comes from Cahuilla, in which stress patterns suggest that only CVV syllables are heavy. In a form like *welnet* "mean one", the *el* sequence is therefore dominated by a single mora. The morphological process of intensification lengthens a consonant, giving *wellnet* "very mean one". Hayes analyzes this process as addition of a mora to which the l of *welnet* is then associated, producing a bimoraic initial syllable. Evidence for the monomoraic/bimoraic contrast comes from the distribution of secondary stress. Syllables following CVV normally receive secondary stress in Cahuilla, and such stress is found on the second syllable of the intensive form *wellnet*.

Another possible contrast involves long vowel versus vowel-homorganic glide, found in Central Alaskan Yupik (Hayes 1989, following Woodbury 1987). If vowels and glides are featurally identical, differing only in that vowels are underlyingly moraic, this contrast should not be possible in a language that assigns weight to coda consonants, as Yupik apparently does. Both Hyman (1985) and Hayes (1989) propose therefore that in at least some languages, vowels and glides differ in their underlying specification for the feature [consonantal].

2.1.2 Structure of the Onset

In the representation shown in (20), only rhyme units are dominated by moras. This structure (assumed in McCarthy and Prince 1986 and Hayes 1986) encodes the traditional division of a syllable into onset (here, segments adjoined to the syllable node) and rhyme (segments adjoined to moras). The various arguments amassed for this constituency (see Fudge 1987) are therefore consistent with this structure. An alternative representation has also been proposed in which each segment is dominated by a mora (that is, a unit on the next level of the Prosodic Hierarchy), in accord with the Strict Layer Hypothesis of Selkirk 1984. Hyman (1985), for example, assumes that each segment is underlyingly associated with a mora but that the universal Onset Creation Rule removes the mora from a prevocalic consonant and associates it to the following mora, yielding the structures in (22):

(22)

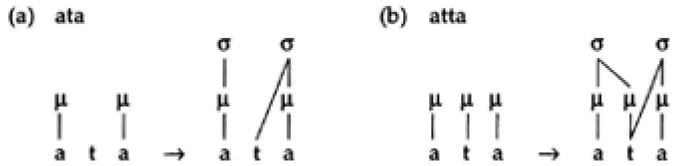


The adjunction of onsets to moras forms a constituent consisting of onset plus first vocalic position. Evidence for this constituent is hard to come by, though Katada (1990) discusses a Japaneses language game which supports it (see also chapter 23, this volume, note 4). In this game, the final CV of a word is used to begin a new word; *tubame* "swallow" is followed by *medaka* "killifish", and so forth. A word ending in a long vowel must be followed by a word beginning with (the second mora of) that vowel: *budoo* "grapes" may be followed by *origami* "folding paper", but not by *doobutu* "animal". And a word ending in a nasal ends the game, since the nasal constitutes the word-final mora, and moraic nasals may not occur word-initially. A few additional arguments have been offered on both sides of the onset adjunction question. Ito (1989) uses the structure in which onsets adjoin to moras to predict the occurrence of epenthesis, which in her analysis groups together a fixed number of moras; however, Broselow (1992) argues for the adjunction-to-syllable analysis on the basis of many of the same facts, using the contrast between syllable-dominated consonants and mora-dominated consonants to predict the site of the epenthetic vowel. Buckley (1992) analyzes certain gestural sequences in Kashaya, which pattern in some respects with single segments, as two gestural units lexically associated to a single mora. Since these sequences occur in onset position, the analysis requires that onset segments be dominated by moras. This analysis brings the mora full circle from its function as encoder of syllable weight to encoder of segmenthood, blurring the distinction between moraic and skeletal tiers.

2.1.3 Representation of Segment Length

Segment length is represented in a skeletal framework as mapping of a single set of features to two skeletal positions. In a moraic framework, long vowels have generally been represented as features mapped to two moras. A framework in which onsets are dominated by moras makes available a similar representation for long consonants. However, since geminate consonants typically serve both as coda to one syllable and onset to a following syllable, the bimoraic representation of consonant length is not generally available in a framework that assumes direct linking of onsets to syllable nodes, with no intervening mora. In such a framework, heterosyllabic long consonants can be represented by means of mapping a set of consonants features to two prosodic positions: mora (for the coda portion of the segment) and syllable node (for the onset portion). McCarthy and Prince (1986) and Hayes (1989) propose that geminates and single consonants contrast in that only the former are associated to a mora underlyingly. Since moraic consonants are possible only in syllable rhyme, and since prevocalic consonants must always form an onset with a following vowel, underlyingly moraic consonants in prevocalic position will end up linked to two prosodic positions, as in (23b):[11]

(23)



Thus, geminates may be represented as moraic single segments, in contrast to accounts in which length is indicated is two positions on the tier defining segmenthood, whether the skeletal tier or, as proposed in Selkirk (1990), the root tier. Monosegmental and two-root structures make significantly different predictions concerning the distribution, behavior, and weight of long segments.

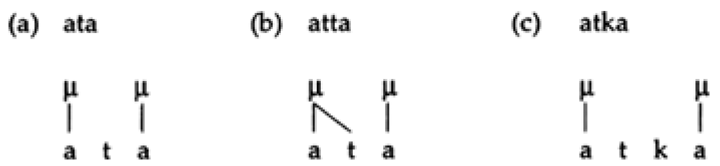
Selkirk (1990) argues for a representation of geminates as a single set of place features mapped to two root nodes. Her major argument involves phonological rules that alter one portion of a geminate, in apparent violation of the principle of geminate integrity. One example comes from Northern Icelandic, in which geminates can split into two different consonants; geminate aspirated stops are transformed to a sequence consisting of *h* plus a single unaspirated stop ($pp^h \rightarrow hp$). Selkirk points out that the single-segment analysis of geminates makes this fission difficult to describe; furthermore, it offers no explanation for the parallels between geminates and true consonant clusters (for example, the sequence lp^h becomes voiceless *l* followed by unaspirated *p*). She proposes that geminate integrity is actually a function of a constraint requiring (roughly) that the heads of multiply-linked features be identical. If geminates are analyzed as consisting of a single set of place features linked to two root nodes, the Icelandic rule, which simply delinks certain features from these root nodes, would not violate this constraint.

Selkirk also discusses the distributional predictions of the monosegmental versus two-root analyses. In the absence of exceptional licensing conditions at the periphery of morphological units, the moraic single segment analysis predicts that geminates should not occur in exclusively syllable-initial or syllablefinal positions. Selkirk agrees that geminates are rare in these positions, but points out that the banning of tautosyllabic geminates may be ascribed to the independently motivated constraints on sonority sequencing within syllables; the same constraints that rule out a sequence of stops, for example, could rule out a sequence of two root nodes specified as stops, even when these are linked to the same place node.

Tranel (1991) investigates the predictions of the moraic analysis of geminates with respect to syllable weight. He points out that moraic representations predict that no language should treat syllables closed by the first part of a geminate consonant (CVGm) as light, since the first half of a geminate must, under the single-segment analysis, be moraic. Thus, a language that lacks the Weight-by-Position rule should contrast syllables closed by true single consonants (CVC), which must be light, with necessarily heavy CVGm syllables. Tranel argues that in fact a number of languages (he cites Selkup, Tübatulabal, and Malayalam; see Blevins 1991 for additional examples) treat both CVGm and CVC syllables as light for stress assignment, although these languages do have a weight contrast: CVV syllables are heavy. Furthermore, he argues, no language appears to treat only CVGm syllables as heavy. This pattern accords with the two-segment analysis of length: the first portion of the geminate is equivalent, for the purposes of Weight-by-Position, to any other coda consonant - but is inconsistent with the single moraic segment analysis.

If, as Tranel argues, CVGm and CVC syllables invariably have the same weight in any given language, various approaches might be taken to build this into moraic theory. Tranel discusses the suggestion of Hayes that Weight-by-Position be viewed as a wellformedness constraint rather than a rule, allowing moraic consonants in some languages but forbidding them in others; this constraint would then delete the moras associated with geminates once they were linked to coda position.[12] One might also interpret the negative setting of Weight-by-Position as forbidding moraic consonants at any level, including lexical representations. In this case, geminates could be represented as lexically adjoined to a preceding vowel mora, as in (24b):

(24)



Onset formation rules would link the intervocalic *t* in both (24a, b) to the onset of the second syllable, yielding a single consonant/ geminate contrast without a corresponding weight contrast. The *t* in (24c) would be adjoined to the preceding mora by regular coda formation rules. Of course, these approaches all presuppose a monosegmental analysis; Tranel's generalization that CVGm and CVC syllables always bear the same weight would follow from the two-root analysis of geminates.

2.2 Arguments for the Mora

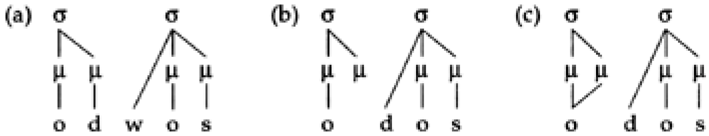
Where skeletal tiers assign a slot to each segment, a moraic tier provides slots (that is, moras) only for segments in weight-bearing positions. Thus, given moraic representations, onsets should be irrelevant for template shape and lengthening phenomena, and empty slots of the sort considered in section 1.3 should all occur in rhyme rather than onset position (_onset/rhyme asymmetry_, section 2.2.1). Furthermore, we expect to find processes that count moras, rather than segments, and for these processes, a heavy (bimoraic) syllable should be equivalent to a sequence of two light (monomoraic) syllables (_mora counting_, section 2.2.2). And finally, a particular language's determination of which segment types can be moraic should show up in all domains in which the mora is relevant (I will call this _moraic consistency_, section 2.2.3). For example, a language that treats CVV and CVC syllables as equivalent for the purposes of stress and accent should display the same equivalence in the satisfaction of morphological templates. This potential to make predictions across different domains is both the most interesting and the most problematic aspect of moraic theory. In the following sections I examine these principles against the evidence from various domains.

2.2.1 Onset/Rhyme Asymmetries

The reduplicative patterns discussed in section 1.5 illustrate various onset/rhyme asymmetries. The optionality of initial consonants exemplified by Agta forms (15) _taktakki_ and _ufuffu_, in which the reduplicative prefix takes the form (C)VC, makes sense once the affix is conceived of in terms of syllable weight: rhyme (moraic) positions must be filled, but the onset (the initial consonant position) is optional. The same optionality is not typical of mora-bearing positions, as illustrated by languages like Mokilese where, if no second consonant is available to give content to the final mora, the vowel is spread (as in (14b, c) _pokpoki_, _paapa_). Once the affix is conceived of as a syllable, the freedom in filling its third position with either a vowel or a consonant is not surprising, since it is possible for both vowels and consonants to be moraic. We would not, however, expect the same interchangeability of consonant and vowel in the initial position of a three-position affix like the Mokilese one, since this position is reserved for the onset. Since there is nothing in a timingtier analysis to rule out such interchangeability, the moraic analysis is more restrictive. There is evidence that points the other way, such as the Mokilese VCC allomorph (illustrated in (17) _allalu_), much of which is susceptible of an alternative analysis such as the one discussed in section 1.5. The Arabic contrast (8b, c) _kattab/kaatab_ is also a problem for both X-slot and moraic accounts, but there is good reason to assume that for most Arabic templates, vocalism is prespecified (Broselow, in press). Thus, templatic morphology seems generally to support the asymmetry of onsets and rhymes.

In skeletal accounts of compensatory lengthening, deleted material leaves a skeletal slot which is then filled by spread of remaining gestural material.[13] However, Hayes (1989) has argued that while deletion of segments from a syllable rhyme often triggers lengthening of a neighboring segment, deletion of an onset segment rarely does. For example, deletion of word-initial or intervocalic _w_ in East Ionic dialects of Greek, as in *_woikos_ > _oikos_ "house", *_newos_ > _neos_ "new" (Hayes 1989; Steriade 1982; Wetzels 1986), results in neither lengthening nor in the appearance of a glide, as one would expect if vowel features were spread to an onset position: spread of _e_ or _o_ to the empty _w_ position in _newos_, for example, should yield _nejos_ or _newos_, respectively (see the Bakwiri case, discussed in section 1.1 above). There is one environment, however, in which a _w_ deleted from onset position does trigger lengthening, illustrated by *_odwos_ > _oodos_ "threshold". But this is just the case in which deletion creates the syllable structure VC.V, which is highly marked and frequently subject to resyllabification, deriving V.CV. If, as Hayes argues, deletion of onset _w_ triggers movement of the _d_ out of the rhyme and into the onset, this leaves an empty rhyme position (25b), which then triggers lengthening (25c):[14]

(25)



Hayes suggests that this pattern of compensatory lengthening triggered by deletion (or movement) from rhyme but not onset is what would be expected if the relevant unit for compensatory lengthening is the mora, rather than the skeletal slot. Even if X-slot theory were modified to include a prohibition against filling onset slots, this asymmetry would presumably not follow from any aspect of the representation itself, as it does when compensatory lengthening is identified as spreading to an empty mora. Much of Hayes's (1989) paper is devoted to arguments that, even with such prohibitions, it would not be possible to restrict the X-slot theory to derive all and only the attested types of compensatory lengthening. It should be observed that a theory such as that of Hyman (1985), in which all segments have underlying weight units, would have to account for the fact that only certain weight units trigger compensatory lengthening.

Hayes (1989) discusses two counterexamples to the moraic account of compensatory lengthening. These include compensatory lengthening triggered by onset deletion in Onondaga (Michelson 1986) and in Samothraki Greek (Newton 1972), both of which involve a change from CrV to CVV. Since CrV sequences are notably subject to reorganization (see Dorsey's Law in Winnebago [Steriade 1990]), Hayes's analysis of these as involving some intermediate stage in which *r* occupied a moraic position seems plausible.

Moraic theory embodies the prediction that underlyingly empty slots should not be found in onset position. A survey of the literature turns up very few such cases. One is French *h-aspiré*, mentioned in section 1.3. Other languages for which empty onset slots in stems have been posited are Onondaga (Michelson 1986) and Seri (Marlett and Stemberger 1983). Interestingly, all these cases involve empty C slots in the initial (never internal) position of a stem, as well as slots that are left unfilled in at least some environments. Such empty slots have often been justified by a contrast with earlier “abstract” analyses which required arbitrary choice of some underlying consonant which was never realized on the surface. However, Dresher (1985) argues that from the standpoint of learnability, an analysis positing empty slots that remain unfilled has no advantage over the positing of some abstract segment. If this position can be maintained, then these cases need not pose a serious problem for moraic theory.[15]

Affixes may also involve empty slots, and one case in which an empty slot in onset position has been posited involves imperfective verbs in Alabama. Verbs with open antepenultimate syllables form their imperfectives by lengthening the onset consonant of the penultimate syllable and adding a high tone to the preceding syllable. Verbs with closed antepenults lengthen the penultimate vowel, which receives a high tone (data from Hardy and Montler 1988 and from Montler, personal communication):

(26) Alabama

	Perfective	Imperfective	Gloss
(a)	balaaka	bállaaka	“lie down”
(b)	hocifa	hóccifa	“name”
(c)	campoli	campóoli	“taste good”
(d)	ibakpila	ibakpíila	“turn upside down”

Hardy and Montler (1988) posit as the imperfective affix an empty X-slot, linked to a high tone, which is inserted in the onset of the penultimate syllable. In (26a, b) this additional slot causes the original onset to move backward to the antepenult (*ba-lXaa-ka* → *bal-Xaa-ka*). The inserted slot is then filled by spread of the preceding consonant, and since tone cannot dock on consonants, the tone moves back to the preceding syllable. In (26c, d), where the preceding syllable is already closed, the X slot (and the tone) remain in the penult, and the X slot is filled by vowel spread. If correct, this analysis argues for X slots rather than moras, which presumably cannot be added in onset position. However, since the additional prosodic position always does surface in syllable rhyme position, it seems reasonable to describe this process as insertion of a mora rather than an onset slot. The problem with this account is then to describe why the mora is added sometimes to the antepenultimate and sometimes to the penultimate syllable – the latter only when the antepenult is either heavy or absent. Lombardi and McCarthy (1991) offer a number of arguments that the mora is added to the final foot of the word: the final syllable is extraprosodic, and since feet are iambic (requiring their lefthand syllable to be light), the final foot includes the antepenultimate only if that syllable is light. One advantage of this analysis is that the mora in question is inserted into the same syllable in which it surfaces (penultimate or antepenult syllables), with no movement required of the high tone from one syllable to another, as in the X-slot analysis.

2.2.2 Mora Counting

At the level of the mora, CVCV is equivalent to a single heavy syllable (an equivalence that can be expressed only indirectly in a skeletal theory). For example, the formation of rustic girls' names in Japanese involves prefixing *o* to the portion of the name containing the first two moras (Mester 1990):

(27)

	Full name	Truncated name
(a)	Yuuko	o-Yuu
(b)	Ranko	o-Ran
(c)	Yukiko	o-Yuki

McCarthy and Prince's (1990a) analysis of Arabic broken plurals involves a similar truncation. The same equivalence of two-mora sequences may show up in augmentation processes as well. For example, the Italian *radoppiamento sintattico* normally makes a syllable heavy in certain syntactic contexts by geminating the following consonant (*le gru selvatiche* ‘the wild cranes’ with [s:], but *selvatiche* with a simple consonant in other contexts). Repetti (1989) argues that the addition of word-final light syllable in the development of certain dialects (Medieval Tuscan *può* > *puone* “s/he can”) represents another realization of the same process.

Constraints on minimal word shape provide another illustration of mora counting. In many Arabic dialects, monosyllabic words must be superheavy (either CVVC or CVCC). Words consisting of a single heavy or light syllable are not allowed, though words consisting of two light syllables are (Cairene *sana* “year”). Assuming that final consonants are extrametrical, this pattern can be analyzed as a requirement that words contain at least two moras.[16] Imperative verbs take the basic shape CCVC, which is subminimal. This is repaired in many Levantine dialects by lengthening the stem vowel: *sʔaal* “ask, masculine singular” (the basic short vowel emerges when the imperative takes a vocalic suffix: *sʔali* “ask, feminine singular”). In Iraqi Arabic, the two-mora constraint is obeyed by inserting a vowel to the left of the stem: *drus* → *idrus* “study”. Thus both dialects enforce the two-mora minimum, one by adding a syllable and one by lengthening the monosyllabic stem. The minimal word in these dialects also constitutes the minimal domain of stress assignment (Broselow 1982), illustrating the consistency of moraic requirements across domains; see McCarthy and Prince 1986 for detailed discussions of the relationship between stress and minimality constraints.

Compensatory lengthening provides another area in which bimoraic sequences, whether disyllabic or monosyllabic, may be expected to count as equivalent. Hayes (1989) analyzes the Old English change of *talə* to *taal* “tale” as spread of the first syllable's vowel to fill the mora freed by deletion of the second vowel.[17] The reverse change is found in the pronunciation of English words by native speakers of Korean, who typically insert a vowel after a syllable containing a tense vowel:

(28)

	English	Korean
(a)	bit	bit
(b)	beat	biti

Park (1992) analyzes this as mora conservation, claiming that vowel length contrasts have been lost in modern colloquial Korean, and that Korean speakers therefore resort to insertion of a syllable to maintain the mono- versus bimoraic distinction of the English forms.

Yet another process related to mora counting is the common shortening of vowels in closed syllables. For example, in Cairene Arabic, vowels shorten before any following consonant within the syllable rhyme: compare *kitaab* "book", where the word-final consonant is extraprosodic, and *kitabha* "her book", where the *b*, because no longer peripheral, loses its extraprosodic status and must be incorporated into the preceding syllable. This shortening can be analyzed as an effect of an upper limit of two moras per syllable (McCarthy & Prince 1990b); the vowel must shorten in order to accommodate a moraic consonant within the same syllable. Since stress, morphology, and minimality constraints all converge on the conclusion that coda consonants bear weight in Arabic, this case provides a convincing example of moraic consistency, a topic we turn to now.

2.2.3 Moraic Consistency

The principle of moraic consistency makes explicit predictions concerning the connection between various areas of the grammer, including stress, accent, templatic morphology, minimality constraints, compensatory lengthening, and vowel shortening. In its strongest form, it leads us to expect that a configuration that has a particular weight for some aspect of grammar should have that weight for all aspects of the grammar. A number of languages – for example, Cairene Arabic, in which the evidence from stress, minimality, moraphology, and vowel shortening disussed above converge to support the moraicity of coda consonants – support this strong form of moraic consistency. Some of the most interesting cases invlove languages in which only certain segment types can be moraic. For example, Zec (1988) argues on the basis of evidence from several domains that Lithuanian sonorant consonants, but not obstruents, are moraic in coda position. First, rising tone accents, analyzed as linkage of a high tone on the second mora of a syllable, are found on syllables with long vowels, or with short vowels followed by sonorant consonants, but never on short-vowel syllables closed by obstruents (see also Kenstowicz 1971; Kiparsky and Halle 1977; Hyman 1985). Second, differences between sonorant consonants and obstruents emerge in such areas of morphology as the formation of infinitive verbs:

(29)

	Present	Infinitive	Gloss
(a)	tupia	tuupti	"perch"
(b)	drebia	dreebti	"splash"
(c)	karia	karti	"hang"
(d)	kauja	kauti	"beat"

The lengthening of the vowels in (29a, b) can be analyzed as mapping of infinitive stems to a bimoraic template; the sonorant-final stems in (29c, d), on the other hand, already satisfy the bimoraic requirement without lengthening.[18] And third, long vowels shorten when followed by a sonorant within the syllable, but not before an obstruent (Osthoff's Law).

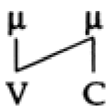
However, not all the evidence from Lithuanian points to the moraicity of sonorants as opposed to obstruents. As Steriade (1991) observes, Lithuanian imposes a minimality constraint on monosyllabic roots: CV roots are not found, though roots of the form CVV or CVC are permitted. Minimality is apparently indifferent to the sonority of a final consonant (*lip* "rise, climb" is one root). The root constraints might conceivably be the remnant of some earlier stage of the language at which weight was indifferent to consonant type. This is not, however, an isolated instance of inconsistency in moraic value. Similar facts are found in Greek (Steriade 1991), Tübatulabal (Crowhurst 1991), and a number of other languages (see Hayes 1992 and Blevins 1991). The next section reviews responses to the failures of moraic consistency.

A number of devices have been used to account for moraic inconsistencies, including rule ordering, formation of complex moras, mutileveled representations in which a segment may be moraic on one level, nonmoraic on another, and the exemption of certain processes from a strict reliance on mora count.

In Archangeli's (1991) analysis of Yawelmani, Weight-by-Position is conceived of as a phonological rule whose application can be delayed until fairly late in a derivation. Archangeli provides convincing arguments that in Yawelmani, mapping of a CVC root to a morphological template consisting of a bimoraic syllable results in lengthening of the root vowel. This indicates that the coda consonant does not count as moraic, since it does not fill the second mora position of the template. However, long vowels shorten in closed syllables - the sort of shortening generally associated with a bimoraic limit on syllables. Archangeli's solution to this paradox orders Weight-by-Position, which assigns a mora to a coda consonant, *after* roots are mapped to templates, but *before* the rule of vowel shortening, which trims syllables down to two moras. Thus, consonants are incorporated into codas at one stage, but do not receive weight until a later stage: Weight-by-Posistion is not (as might plausibly be assumed) an automatic consequence of incorporating a consonant into the syllable coda.

A situation that is in some sense the converse of the Yawelmani case occurs in several Arabic dialects. As discussed above, Cairene Arabic permits CVVC syllables phrase-finally but not internally, a pattern that can be attributed to a bimoraic limit on syllables plus extrametricality of phrase-final consonants. However, several dialects do permit word-internal CVVC syllables, even though coda consonants otherwise count as heavy for stress, morphology, and minimality constraints in these dialects. Syllables of the form CVVC arise only from syllabification of a consonant that has lost its extrametrical status through suffixation, or has lost the vowel of its own syllable through syncope (compare Sudanese *kitaabha* "her book" and Cairene *kitabha* < *kitaab* + *ha* "her book"); since CVVC syllables do not occur underlyingly, it seems unlikely that these dialects simply tolerate bimoraic syllables. Broselow (1992) and Broselow, Huffman, Chen, and Hsieh (in press) argue that VVC sequences are actually bimoraic (an analysis supported by evidence from Arabic poetics and durational data), resulting from a rule of Adjunction-to-Mora which links the consonant to the second mora of the long vowel. Adjuction-to-Mora is restricted to derived environments (and to particular levels of the grammer, which vary across dialects). Cairene Arabic either lacks Adjunction-to-Mora at the relevant levels, or has an additional rule delinking a vowel from the second mora in the following structure:

(30)



An alternative to delinking might involve a difference in the phonetic interpretation of structures like (30) in Cairene versus Sudanese; these dialects would differ in the timing of the vowel and consonant gestures linked to a single mora.[19]

An alternative to these derivational accounts of moraic paradoxes, suggested by Hayes (1991), provides different but simultaneous levels of representation for the same structure. Hayes proposes a moraic grid, where the number of grid marks associated with a segment is directly correlated with its sonority:

(31)

(a) ta (b) taa (c) tap

μ μμ μ

μ μμ μμ

a a ap

Processes that treat coda consonants as moraic would refer to the lowest level on the sonority grid, while those that count only vowels would refer to the next level. Presumably, a third level of representation is needed for languages like Lithuanian, in which various processes treat sonorant consonants but not obstruents as weight-bearing.

This dual representation is reminiscent of (and possibly equivalent to) the sort of distinction made in a nonmoraic theory between the subsyllabic constituents nucleus and rhyme. In the nucleus versus rhyme approach, the two rhyme positions in (31b) would be contained within the nucleus, while in (31c) the rhyme would consist of the single-position vocalic nucleus plus the non-nuclear consonant. Steriade (1991) compares the efficacy of the moraic versus subsyllabic constituency approaches in accounting for various facts in Greek and other languages, and concludes that moraic theory, properly constrained, is more restrictive than the nucleus/rhyme approach. Among her proposals to restrict moraic theory is one which accommodates only specific types of moraic paradoxes. She claims that most of the attested moraic paradoxes involve syllable types which are light for the purposes of stress assignment, but heavy for morphological templates and minimality constraints (except for templates and constraints stated in terms of feet, since feet are the the units of stress assignment). She argues, therefore, that CVC syllables are always bimoraic – that is, that all languages have Weight-by-Position – but that a language may restrict the set of possible stress-bearing (and/or tone-bearing) segments to those above a particular sonority threshold. Rather than employing dual representations or rule ordering to account for moraic paradoxes, this proposal simply gives up the notion that stress rules are sensitive only to the number and arrangement of moras.

One potential objection to this approach involves languages like Yawelmani, Lithuanian, or Kwakwala in which templatic morphology also gives special status to a set of higher-sonority elements. In Zec's (1988) framework, the lower-sonority elements simply cannot be mora-bearing. Though Steriade assumes that no segment is obligatorily nonmoraic, she does distinguish unconditionally moraic segments (those which always project a mora) from conditionally moraic ones (those that are moraic only in appropriate positions – essentially, those where Weight-by-Position is applicable). Templatic mapping therefore needs somehow to distinguish conditionally and unconditionally moraic segments, in order to ensure that only the former may be used to satisfy the moraic requirements of templates. Since this approach does not predict moraic consistency between stress and other moraically-based processes, different mechanisms are needed to account for why a language like Kwakwala allows sonorants but not obstruents to count both for stress assignment and for the satisfaction of morphological templates.

Clearly, moraic paradoxes pose a serious challenge to moraic theory, as evidenced by the range of devices proposed to handle them. One hopes that a better understanding of the universal principles governing the structure of prosodic units and the functioning of rules in a grammar will allow this theory to account for failures of moraic consistency without losing its predictive power. Work on such constraints is just beginning.

2.3 Mora-Syllable Relationships

Two additional questions in moraic theory concern constraints on the number of moras within a syllable, and constraints on the relationship between moras and higher units of prosodic structure.

Both McCarthy and Prince (1986) and Steriade (1991) suggest that syllables should be limited universally to an upper bound of two moras. Most cases of apparently heavier syllable types (such as CVVC) can be analyzed either as bimoraic (as in the Arabic dialects discussed above) or as comprising a bimoraic syllable plus extrametrical element. However, Hayes (1989) argues that trimoraic syllables must be allowed, if only as a marked option. The evidence involves first, three-way contrasts among syllable types: for example, in Hindi, CVVC and CVCC syllables, even word-internally, are treated as equivalent to a bimoraic syllable followed by a monomoraic syllable, while in Estonian, vowels can be short, long, or overlong. The second sort of evidence involves compensatory lengthening in trisegmental syllable rhymes: Old English *θaηxta* > *θaaxta* “thought”. If η shares a mora with either of its flanking segments, its deletion should not trigger lengthening, since its mora would still be occupied; therefore, the syllable must be trimoraic. Since fairly few cases motivating trimoraic syllables have been amassed (but see also van der Hulst 1984), the necessity for giving up a universal constraint on maximal number of moras per syllable is still unresolved. A related question is whether syllables must contain at least one mora, a proposition disputed by Hyman (1985). Hyman argues that patterns like the one found in Chuvash, in which stress falls on the last full vowel of a word, but skips either of the two “reduced” vowels, can be best described by representing reduced vowels as moraless (see Odden 1986b for discussion).

While the preceding discussion has focused on moras as constituents of syllables, the assumption that a mora is always dominated by a syllable is by no means generally accepted. Hyman (1985) argues that in Gokana, for example, all those areas generally used to motivate syllables – distributional constraints, the environments of phonological rules, and the composition of higher-order units such as feet – can be accounted for by the use of moraic and morphological structure; thus for this language, at least, syllables are simply redundant. Zec (1988) and Bagemihl (1991) argue that the mora can serve as a prosodic licenser, protecting segments from stray erasure, a role generally reserved for the syllable. Bagemihl's argument involves reduplication in Bella Coola, a language that permits long sequences of obstruents within words. One type of reduplication copies the first obstruent-sonorant sequence found in the word:

(32)

(a)	qpsta	qps*t*ata	“to taste” (iterative)
(b)	tqn̩k	t*qn*qn̩k	“be under” (underwear)
(c)	st’qʷlus	st’*qʷl̩*qʷlus	“black bear snare” (diminutive)

Bagemihl analyzes this as prefixation of a core syllable (CV) template to the first syllable of the word, where syllables consist maximally of CCVVC, and where the initial consonant sequence must consist of an obstruent followed by a sonorant. Left-to-right mapping to the syllable template puts the sonorant consonant in syllable nucleus position in (32c). The obstruents skipped over in reduplication (for example, the sequence *qps* in (32a)) are dominated not by syllable nodes, but solely by moras. Allowing some segments to be licensed by moras rather than syllables increases the power of a grammar, since it permits virtually any sequence of segments to be a possible word; however, Bella Coola may in fact warrant this sort of freedom. On the other hand, the assumptions (a) that these obstruents are indeed contained within syllables (as many Salishanists have traditionally done) but (b) that reduplication seeks out the first syllable with a rising sonority profile may provide the basis of an alternative account.

3 Conclusion

This paper has reviewed the devices used in generative phonology to represent segmenthood, length, morphological template shape, and syllable weight. Two families of proposals were compared: those involving a skeletal or timing tier, which provides a slot for each segment, and those employing a moraic tier, which provides slots only for segments bearing weight, supplemented by a root tier, which anchors the features defining a segment. The moraic definition of length and morphological shape was argued to be at least potentially more restrictive than the skeletal representation, since it distinguishes weight-bearing segments from those which cannot bear weight (for example, segments in onset position). However, problems such as apparent inconsistencies in syllable weight found in various languages have led to some weakening of moraic theory. The development of a theory that is powerful enough to accommodate the facts but constrained enough to make interesting predictions is the task of future reserch in this area.

1 Hombert's account of these facts does not rely on double linking, but rather on the assumption that (4a) is underlyingly monosyllabic. However, the data reveal an apparent contrast between monosyllabic vowel

sequences, as in *lìòßá* "door" (game form *ßààlíó*) and vowel sequences like those in (4a), which undergo glide formation.

2 But see Odden (1986b) and Broselow (1984), among others, for arguments that such representations do occur.

3 Compare this approach with, for example, the Adjacency Identity Constraint of Guerssel (1977), a constraint which prohibits certain sorts of rules from applying to identical sequences. This constraint must explicitly distinguish tautomorphemic from heteromorphemic from heteromorphemic geminates. The different treatments of geminate integrity and alterability in the linear and nonlinear frameworks provide a nice example of the shift in focus from rules to representations in the development of generative phonology.

4 But see Yip (1988) and Hoberman (1988) for alternative analyses of this pattern.

5 Archangeli (1991) argues for an alternative treatment of segments that do not fit into the morphological template; in Yawelmani, such segments are simply syllabified, triggering epenthesis where necessary.

6 As Goldsmith (1990) points out, the inverse case – a unit on the gestural tier that is not associated with any skeletal slot – does not seem to occur, at least in stems.

7 Although the CVV affixes surface as CV, Finer shows that this is a consequence of a general process of vowel reduction, and that the quality of the surface vowel cannot be predicted unless both vowels are copied.

8 McCarthy and Prince suggest that the prefix may be definable simply as a syllable, with an independently motivated rule of boundary lengthening adding a mora between prefix and stem; Levin 1985a argues against this position, however.

9 I have ignored the problem of the transfer of length from base to reduplicative affix which occurs in Mokilese as well as a number of other languages; see Clements (1985b), Steriade (1988b), and McCarthy and Prince (1986, 1988, 1990a) for various approaches to this problem.

10 This proposal brings the root tier closer to the C/V skeletal tier of McCarthy's earlier proposal. Interestingly, the earlier proposal was made in the context of a framework that assumed fully specified distinctive features. More recent work in feature geometry frequently assumes either privative features or radical underspecification of features. If both [consonantal] and [sonorant] can be unspecified in underlying representations, the possibility of null root nodes arises.

11 Note that in a moraic framework the vowel-glide sequence in the Bakwiri form (5a) *mbowa*, from /*mboa*/, would have a structure similar to a geminate consonant, since the *o*, linked to its own mora, is spread to the onset of the following syllable.

12 As Tranel points out, this approach is at least potentially inconsistent with an analysis that allows Weight-by-Position to be ordered among phonological rules, as does Archangeli's (1991) analysis of Yawelmani discussed in section 2.2.3.1. If Weight-by-Position can be turned on or off at some point in the derivation, we should expect to find stages in which CVGm can contrast with CVC syllables.

13 Compensatory lengthening has attracted considerable attention in nonlinear phonology (see Wetzels and Sezer 1986). Hock (1986) argues against the exclusively phonetic account of CL propounded by de Chene and Anderson (1979).

14 But see, for example, Rice (1989) for arguments that this sort of resyllabification is generally prohibited.

15 An interesting case for comparison involves the postulation of an underlying pharyngeal fricative in Maltese (Brame 1972). As in French, the postulated segment, though never realized on the surface, has a number of phonological effects. In contrast to the French case, however, the Maltese segment patterns not just with consonants in general but with a specific articulatory calss of consonants (the gutturals), requiring that the consonant be specified with gestural material as well as a skeletal slot.

16 CVV monosyllables, however, do not occur. Final long vowels are generally banned in dialect forms; exceptions include final clitics, for which there is some evidence for assuming *h* following the vowel (see Broselow 1976; McCarthy 1979).

17 This analysis requires some auxiliary assumptions to ensure that the final / in *taal* does not associate to the mora stranded by vowel deletion. Hayes argues that the rule filling empty moras via spreading from the left applies before stranded segments are incorporated into syllables. The / then associates to the second mora of the syllable, rendering *taal* bimoraic.

18 This analysis differs slightly from that of Zec (1988), which posits a rule of mora insertion in infinitives; the inserted mora remains unrealized in an already bimoraic syllable.

19 A similar approach might be extended to Yawelmani. Archangeli's major argument that coda consonants must be mapped to stem templates early in the derivation (although they do not fulfill weight requirements of templates and therefore are argued not to receive weight until later) involves so-called "ghost consonants," which surface only under certain prosodic conditions. Thus, in the suffix *(h)atin*, the ghost *h* appears after a stem ending in one but not two consonants: *cawhatin* (←*caw* + *hatin*) but *hognatin* (←*hogn* + *hatin*). In these forms, Archangeli claims, the ghost consonant appears only when there is no other free consonant available to serve as onset for *a*. It is therefore necessary that the *w* in *caw* + *hatin* be mapped to the stem template to distinguish this case from *hogn* + *hatin*, in which *n* remains free even after the stem template is maximally satisfied. To sketch one possible alternative in which consonants are not mapped to coda position until later, one could assume that only the minimal material necessary to satisfy the stem template is mapped to that template (giving [*ca*]$_\sigma$ *whatin* versus [*ho*$_\sigma$ *gnhatin*). A principle of optimal syllabification in the spirit of harmonic phonology (Goldsmith 1993a; Prince and Smolensky 1991b, 1993) might then ensure that ghost consonants are included in syllables only if their inclusion does not increase the number of syllables in the word. Since both possible syllabifications of CVC stems are equivalent in number of syllables (*cawhatin* versus **cawatin*), the ghost consonant is included. But in CVCC roots, inclusion of the ghost consonant cannot be accomplished without increasing the number of syllables (*hognatin* versus **hoginhatin*).

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