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THE AUTOSEGMENTAL AND METRICAL NATURE OF TONE TERRACING

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1. INTRODUCTION

Tone terracing is a term commonly used in reference to the set pf interrelated phenomena known as downdrift, downstep, upstep and upsweep, which have been widely observed among many African languages and some American Indian languages.* The most commonly reported of these phenomena are downdrift and downstep. Downdrift is generally defined as an automatic progressive overall lowering of pitch throughout a phonological phrase. Thus in a sequence of alternating high (H) and low (L) tones, for example, each occurrence of H (or L) is slightly lower in pitch than the preceding occurrence of the same tone, so that the overall pitch pattern of the phrase is a downward "terraced" one. Generally, this type of lowering does not occur between adjacent occurrences of the same tone. A well known example of downdrift is the following sentence from Akan (Schachter 1961:235), which has the underlying tone sequence as indicated in (1), but a surface representation with six phonetically distinct levels of pitch, as indicated in (2):

(1) me-de-me-n-na-m-fo-no-ba-a-me-fi
L L H H L L L H H L H L
'I brought my friends to the house.'

(2)


As a result of downdrift, an underlying H at the end of a long phonological phrase may be realized on a lower pitch than a L occurring in an earlier part of the phrase.

The process of downdrift is automatic in that given any sequence of tones, every H after L is always one step lower than a preceding H and every L after H is always one step lower than a preceding L. Occasionally, a drop in pitch is observed to occur on a H immediately after another H. The position of such a drop is not directly predictable from a given surface sequence of tones. This drop is referred to as downstep.

The phenomenon "upstep" has the characteristic of raising the pitch of a tone one step higher than a preceding occurrence of the same tone. In the position where the tone is expected to undergo downdrift, upstep brings the tone back to a pitch level as high as the preceding occurrence, so that it appears as if no downdrift has occurred in this position. The occurrence of "upsweep" is less frequently observed. It involves the successive overall raising of pitch over a sequence of some sort.

The processes of tone terracing have been described and analyzed in various ways in the literature. In this paper I will examine the essential properties of tone terracing, and address the problem of what an optimal theory of formal representation may look like that best accounts for these properties and gives a principled explanation for their clustering. In section 2, I will outline the major features of terracing. It is then proposed in section 3 that a correct understanding of the types of phenomena under consideration requires (a) that we draw a clear distinction between matters of tone and matters of pitch; (b) that tone and pitch should be represented as two autonomous levels such that rules may apply on one level without regard to the internal structure of the other level; and (c) that, like stress, tone and pitch should be given a metrical treatment. In section 4 I will compare the theory with earlier proposals and show that these earlier attempts are inadequate either in that they do not make correct empirical predictions or in that they do not capture real significant generalizations, or both. In the last section I will return to the proposed theory and make a number of extensions and refinements to accommodate more complicated cases of terracing.

2. IMPORTANT PROPERTIES OF TONE TERRACING

Among the features of tone terracing that have been reported in the literature, the following are generally held to be true:

(a) Since the occurrence of downdrift is automatic, it does not necessitate the recognition of additional tonemes. For example, in a two-tone language in which downdrift occurs, for each phonemic tone recognized, there is at most one different kind of tone following or preceding it. The status of downstep, on the other hand, may be regarded as partially phonemic, in that its position of occurrence is not directly predictable from the surface though, once its position is known, the way it influences the pitch realization of a phrase is predictable. Each downstep H establishes a ceiling for all following H tones, so that following a downstep H there is again at most one contrasting tone. This fact crucially distinguishes a downstep H in a two-tone language from what might be recognized as a mid tone in a three-tone language, which would be fully phonemic in that there could be two contrasting tones found after and before it.

(b) The interval in terms of pitch values between a H and a following L, or between a L and a following H, remains relatively constant throughout a phonological phrase. This fact can be easily seen from the representation given in (2) above. The interval between the second H and the immediately following L, for example, is the same as that between the fourth H and the immediately following L, and that between the fifth H and the following L. This fact indicates that underlying tonal contrasts are somehow "preserved" despite the extent to which terracing has occurred to influence the realization of tones.

(c) The distance in pitch height between two occurrences of the same tone in a terraced sequence is often not equal to (and is usually less than) the distance between two phonemic tones. For example, for a given speaker a H may be realized at a pitch level higher than a following L by 80 Hz on the fundamental frequency, while a downstepped or downdrifted H may be lower than its preceding H only by 20 Hz or so. This fact can again be seen directly from the representation given in (2). The drop that occurs on the third H, for example, is smaller in size than what happens between a H and a following L, since this H is still higher than the preceding L.[1]

(d) A related point is that the ratio of the amount of drop involved in terracing in relation to the distance between phonemic tones need not be constant in a given language, or even for a given speaker. There is enough indication that this is the case. For example, in Clifton's (1976) study of Twi, the sentence in (3) below is given two distinct pitch representations, as (3b) (p. 182) and (3c) (p. 187):

(3)	a.	mẽ	sekãn	foforo	kɛseɛ	no	nyɛ	
		H	!H!H	H!H H	L HH	H	L H	
		'My other big knife is no good.'						
	b.	1	2 3	3 4 4	6 55	5	7 6	
	c.	1	2 3	3 4 4	7 55	5	8 6	

In (3a), a H immediately after ! represents a downstep H. In (3b) and (3c) integers are used to represent pitch height, with the higher numbers indicating lower pitch values. In both (3b) and (3c), each instance of downstep or downdrift is represented by a drop of one pitch increment from the preceding occurrence of the same tone. The contrast between a H and a following L, on the other hand, is indicated to have the value of two pitch increments in (3b) (the contrast between *4* and *6* or between *5* and *7*), twice the amount of each instance of terracing, but in (3c) this contrast is indicated to be three times the amount of each instance of terracing (three pitch increments between *4* and a following *7* and between *5* and a following *8*). Whether or not these are precise reflections of the actual variations, the fact that both transcriptions are used indicates the possibility of variation.

Another indication of the variation is provided by the phenomenon of "speech planning" (Welmers 1973:88). It happens that speakers must vary the amount of pitch drop that occurs in terracing based upon the length of an utterance, the longer the utterance, the less pitch drop at one time. This is understandable in that one has a limited pitch range within which to realize an indefinite number of levels resulting from terracing in utterances of varying lengths.

Still another indication of the variation is the fact that speakers not only differ with respect to their pitch range (as observed between male and female speakers), but also vary their pitch range depending upon speech situations. A Chinese radio announcer, for example, uses a much wider pitch range at work, so that the tones are more clearly distinct, than when he or she speaks on informal occasions. Thus the amount of pitch drop per instance of terracing may vary from one situation to another, depending upon the pitch range used in each situation.

(e) Downdrift of a sequence of the form H L H L H ... is often perceived in a different way than downdrift of a sequence of the form L H L H L ... In particular, in the former case, downdrift is perceived as involving a lowering of a non-initial H (among others), while in the latter case, downdrift may be perceived as involving a "raised" initial L.

(f) Tone terracing does not occur phrase-initially. In Armstrong (1968:51), for example, this fact is simply built into the definition of downdrift: Downdrift is defined as "the tendency of *non-initial low tones* to pull succeeding high and mid tones downwards in pitch." The lack of phrase-initial downstep has also been indicated by various writers (e.g. Peters 1973).[2]

(g) The amount of pitch drop that occurs at each instance of phonemic downstep is exactly the same as that which occurs at each instance of automatic phonetic downdrift within a given phonological phrase. In the Twi sentence above, for example, each instance of downstep !H involves the drop of one pitch increment, as seen between the values of the first and second tones in (3); and each instance of downdrift also involves exactly the same amount of drop, as seen between any two Hs separated by a L. This fact shows that downdrift and downstep have something in common, and should be somehow related.

(h) In a sequence involving both downdrift and downstep, a downstep H always occurs after another H; there is never a downstep H immediately after a L. One can again see this from the Twi example above.

The eight properties that we have outlined above are more or less well known and generally held to be true. Let us now consider the following question. Assuming that these are true properties of tone terracing, what are the generalizations, if any, that they express, and how should they be treated in an optimal theory of mental representation? Any theory that aims to adequately account for the phenomena of tone terracing must take into consideration all of these properties as well as whatever generalizations they express. We now turn to the task of constructing such a theory.

3. AN AUTOSEGMENTAL-METRICAL ACCOUNT

Let us first consider what possible generalizations may be drawn from the properties outlined above. A look through these properties reveals certain interesting common features among them. On the basis of their common features they seem to fall naturally into three groups. In particular, the first three properties, indicated in (a), (b), and (c), jointly indicate that tone terracing does not affect underlying tonal contrasts, or that matters of tonal contrasts are quite distinct from matters of tone terracing. The next three properties, indicated in (d), (e), and (f), suggest the generalization that there is nothing "absolute" in value, either in tonal contrasts or in matters of tone terracing. Rather, what is relevant is the *relative* value of tones or pitch. A H is relatively high in relation to a L. A tone having undergone downstep is lower in relation to a preceding occurrence of the same tone. The actual pitch values of these entities are largely irrelevant for linguistic purposes. Finally, the last two properties, (g), and (h), both suggest that downdrift and downstep are closely related phenomena.

The generalizations indicated may not be entirely obvious at the moment, but I will assume them to be correct and go on to consider possible ways to account for them. They should become clearer as we continue. Consider the first generalization. One way to capture it is to characterize tone terracing as a process that operates on an extra-tonal level without regard to the internal structure of the tonal level. To see how this may be done, it is useful to draw a distinction between the notions of pitch range, or register, and tone.

Tones are linguistically abstract entities expressing, in the languages in which they occur, an *opposition* between any two tone-bearing units (rimes or vowel-nuclei) within a given range of pitch. Pitch, on the other hand, corresponds more closely to the values of fundamental frequency. A register, or pitch range, sets the range within which contrasting tones are defined.

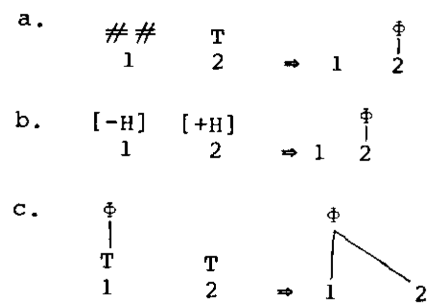
Given this distinction, let us now look at tone terracing in the following way. Since terracing preserves tonal contrasts, we may say that it incolves the shifting of the register only, but not of the tones. More specifically, I propose that (a) tones and pitch registers be represented as two autonomous levels, and (b) terracing be represented as a process operating in the registral level alone, making no reference to the internal structure of the tonal level. This proposal thus incorporates the theory of autosegmental phonology of Goldsmith (1976) and further extends it, claiming that, just as tones constitute an autonomous level somewhat independent of segments (as Goldsmith argues), registers also constitute an autonomous level somewhat independent of tones (and of segments).

As for the second set of properties, I propose that a natural extension of the "metrical" theory of stress of Liberman and Prince (1977) will serve our purpose of capturing the generalization that seems to underly them. Liberman and Prince argue that stress values are entirely relative, and that an adequate system of representation should not make crucial use of integers, such as [+ 3 stress], etc., as in the system developed in Chomsky and Halle (1968). Instead, they provide a system whereby stress-bearing units are organized under a tree each of whose nodes is labeled as either relatively strong or weak in stress in relation to its sister node. The notion of relative degree inherent in their approach may be easily extended to our treatment of tones and of tone terracing.

Finally, in order to capture the generalization that downdrift and downstep are closely related phenomena, a plausible idea is to analyze them in such a way that they involve some common rule or principle in the system we propose.

These are the ideas that may lead us to the right kind of theory required. I will now spell out one mode of execution that will put these ideas to work. I propose that every sequence of tones is organized into a sequence of formal objects called "tonal feet," in much the same way that a sequence of segments is organized into a sequence of formal objects called syllables. These tonal feet are then regarded as the basic pitch-bearing units upon which the assignment of pitch register values will occur, in much the same way that the syllables (or rimes) are the basic tone-bearing units. The process of foot-formation is carried out in accordance with the rules in (4) below:

(4) Foot Formation:



The first two rules provide that, scanning from left to right, the initial tone of a phrase (as in (4a)), as well as every H immediately after a L (as in (4b)), is assigned an independent foot node, indicated here by the symbol Φ. Every tone not assigned a foot node either way is then associated by the provisions of (4c), which may apply iteratively. The feet are the basic pitch-bearing units (PBU's). Since tones are defined within pitch registers and must be realized in terms of pitch, the rule (4c) may be regarded as a way to satisfy the following R(ealization)-Criterion:

(5) R-Criterion: Every tone is assigned to one and only one pitch-bearing unit.

The sequence of tonal feet that results from the rules in (4) will be the input to the rules of pitch assignment that account for the phenomena of tone terracing. For downdrift, pitch assignment is carried out by (6).

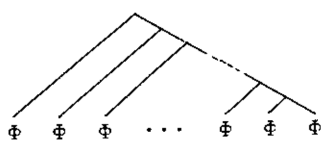
(6) Pitch Assignment:

a. Assign a right branching tree to a sequence of tonal feet.

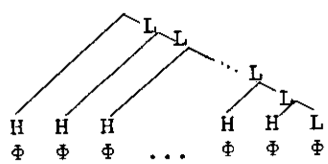
b. For each pair of two nodes N_1 and N_2, label N_1 as L iff it branches. (If a node is not labelled L then it is H.)

The result of applying (6a) to any sequence of tonal feet will be a tree of the form (7a), which is then labelled as (7b) by (6b):

(7) a.



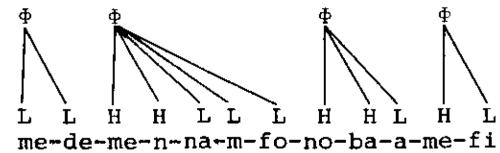
b.



The rule (6b) is an adapted version of one of the universal labelling conventions provided in Halle and Vergnaud (1979), which contains a number of extensions of Liberman and Prince's metrical theory of stress. The result (7b) is achieved by requiring that the rule disregard, or be "blind" to, the internal structure of any foot (whether it branches or not), taking the sequence of feet as an autonomous level, with each foot in the

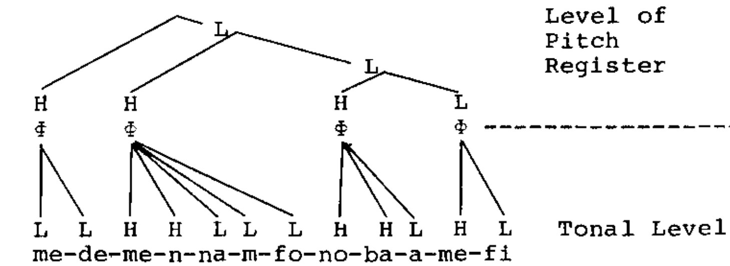
level being considered an autonomous non-branching whole. To illustrate, the Akan sentence considered above in (1) has the following form after foot-formation (4a-c) applies:

(8)



The pitch assigment rules (6a,b) will turn this into (9):

(9)



This is the final output of our rules. It is not, however, a direct phonetic representation of the utterance. It gives only a relational structure showing the relative pitch height of the tones, but says nothing about the absolute pitch values at any point in the tree. It says that the tones that belong to the first foot are realized in a higher register than the tones belonging to the second foot, and those of the second foot are realized at a higher pitch than those of the third, etc. The progressive increase in the depth of embedding under a L node in the tree of the registral level corresponds directly to the progressive pitch drop involved in downdrift. Thus, there are three L nodes above the last foot, two above the third foot, and one above the second foot, but none above the first foot, in the representation above. This directly corresponds to the fact that tones in the second, third, and fourth feet have been lowered by one, two, and three steps, respectively, though not the tones assigned to the first foot. The amount of drop per instance of pitch lowering represented at the autonomous registral level is not related to the distance in pitch between a H and a L within the tonal level. The ratio of the amount of pitch lowering in relation to the amount of pitch difference in tonal contrasts cannot be determined by any general system of representation, but varies from language to language, speaker to speaker, and even from utterance to utterance.

Up to now we have considered only cases of downdrift. Let us turn now to downstep. It is generally agreed that downstep does not differ significantly from downdrift, except in that its position is unpredictable from the surface. The similarity of these two processes is readily seen from one of the last two properties discussed in section 2. One plausible hypothesis on the status of downstep is that it is simply downdrift except that its position of occurrence must be lexically marked. Thus, the status of downstep is like that of the pitch accent in, say, Japanese, where the position of the accent must be lexically marked, though everything else can be derived by rule. On the other hand, it has been suggested that many cases of downstep are in fact cases of downdrift made opaque due to vowel deletion. Thus, it has been suggested that the downstep in the well known example below is the result of a simple application of downdrift preceding a rule of vowel deletion:[3]

```
(10)   H     L H
      /me    ɔbo/      'my stone'
      [ ¯    _ ¯]      underlying representation
      [ ¯    _ -]      by downdrift
      [ ¯      -]      by vowel vowel which deletes
                       both the vowel and the tone
       me    bo
      [ ¯     - ]      output
```

Neither the phonemic nor the purely phonetic approach are entirely satisfactory, however. The phonemic approach is defective in that there are many cases of predictable downstep (such as (10)).[4] Furthermore, as Clements (1979) has shown, the purely phonetic approach is untenable not only because the ordering relation required in the hypothesis above is problematic, due to the fact that downdrift is a lower-level rule than vowel deletion, the latter of which often subject to morphological conditioning, but also because there are languages or sentences where downstep alone, but not downdrift, occurs. For example, in Hyman and Tadadjew (1976), it is indicated that Dschang-Bamileke has downstep, but no downdrift. Another such language is Kikuyu, as reported in Clements (1979) and Clements and Ford (1979). Furthermore, in languages where downdrift does occur, it occurs only in certain sentence types, e.g. declaratives. In other sentence types, no downdrift occurs, though one may also find occurrences of downstep here. In all of these cases, downstep cannot be treated as a special case of downdrift.

In Clements and Ford (1979), it is argued that downstep has the status of a floating L tone which triggers pitch lowering on all following tones. The existence of a floating tone is easily handled within an autosegmental approach, according to which the deletion of an element in the segmental level need not entail the deletion of an element in the tonal level. Their approach solves the ordering problem associated with (10), allowing vowel deletion to occur before pitch lowering. There are also a number of other facts which they cite in support of this analysis. I will adopt it, and analyze downstep as involving the following rule of foot formation:

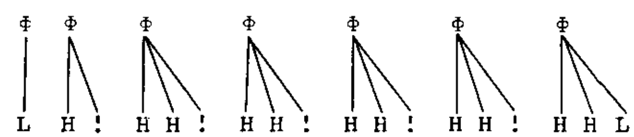
```
(11)                       Φ
         L    H            |
         1    2    →    1  2
```

Condition: 1 is unassociated with any segment.

To account for the relationship between downdrift and downstep, I assume that they differ minimally only in that while downdrift involves the foot formation rule (4b), downstep involves the rule (11). All the other rules proposed above, namely (4a), (4c) and the pitch assignment rules in (6), are involved in both downdrift and downstep.[5] For illustration, consider the following sentence from Efik (Winston 1960:186):

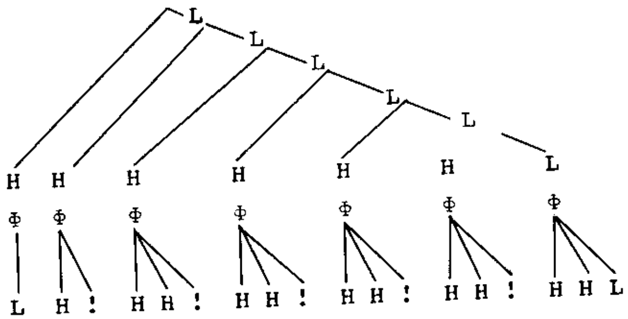
```
(12)  L  H !H    H !H    H !H    H !H   H!H   H  L
      Ekpenyɔŋ   emen    inuen   ɔnyŋ   edi   ufɔk
      'Ekpenyɔng picked it up and came home.'
```

Each ! stands for a floating L tone. By the downstep rule (11), each H immediately following this floating tone will be assigned to an independent foot node. By the downdrift rule (4b), the first H tone will also be assigned to an independent foot node. Furthermore, the phrase-initial L tone is assigned to a foot by (4a). Finally, all remaining tones will be associated according to (4c). These processes of foot formation thus organize the tonal sequence in (12) into the following form:

(13)


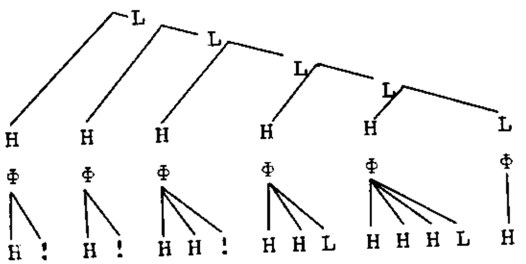
Finally, the pitch assignment rules in (6) apply to give the final output:

(14)



Since the floating tones are unassociated with segments, they are simply phonetically "empty categories," and may be ignored by convention at the final level of phonetic representation. All relevant information concerning the pitch pattern of the sentence is contained in (14). Similarly, the Twi sentence cited above has the following representation after (4), (11) and (6) have applied:

(15)



This metrical tree can be converted easily into an integer representation if one wants to, after one determines what value to assign to each drop in pitch in the register level and what value to assign to the distance between H and L in the tonal level. Thus, either one of the integer representations given in Clifton (1976), as indicated in (3), can be obtained from (15), depending upon actual speech situations.

4. HOW THE PROPERTIES FALL OUT

We have proposed an autosegmental and metrical system of representation of tone terracing and illustrated the way it works. Let us see how it may account for all the properties indicated in section 2 and capture the general-

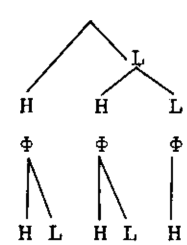
izations that underly them.

Consider the first three properties again. Since we have adopted an autosegmental approach to both tones and pitch registers, it is natural to expect that processes that operate on one autonomous level need not affect the content of the other level. Thus tone terracing (or rather register-lowering) does not necessitate the recognition of additional tones (in the tonal level). Preservation of tonal contrasts by tone terracing is also a natural consequence of this system, because register lowering applies to each tonal foot or pitch-bearing unit as a whole (rather than to tones), without affecting the internal relationship of contrasting tones within each foot. Furthermore, it is also a natural consequence that the amount of pitch drop occurring in terracing need not be equal to the distance between two contrasting tones.

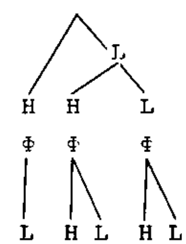
The next three properties may be taken as natural consequences of our system because of the metrical view we have adopted. Thus, the variation in the amount of pitch frop per instance of terracing, as well as in the ratio of this drop in relation to the difference between contrasting tones, indicates that the actual values of pitch to be assigned to a sequence of tones are subject to factors that are largely pragmatic and that cannot be, and should not be, fully specified in a formal grammar. As is already obvious, these factors are completely abstracted away from our system.

The metrical view also explains the difference in perception (and realization) that may happen between a sequence of the sort H L H L H and one of the sort L H L H L. This is because all independent phonological phrases may be pronounced at as high a pitch level as each other. More significantly, according to our system, the two sequences have the following representations:

(16) a.



b.



In the tonal level of (16a), the first H tone does not undergo downdrift, but the second H does, as it is assigned to the second tonal foot. Since the first L in this sequence belongs to the first foot, the distance between the L and the second H is shortened. Therefore, the second H is realized and perceived as being lowered from the height of the preceding H by one step. On the other hand, in the tonal level of (16b), the first occurrence of H belongs to the second foot, with the first foot containing only one tone, L. There is also a shortened distance between the initial L and the first H. But since the amount of tonal contrast is usually greater than the amount of contrast resulting from terracing, the H tone that occurs in the second foot is still higher than the L occurring in the first foot. Therefore, within this sequence, the tone with the highest pitch is the second tone, namely the first H. Now, since (16a) and (16b) are independent phonological phrases, the tone of the highest pitch in (16b) can be as high as the tone of the highest pitch in (16a). Therefore, while the shortened distance in (16a) between the first and the second foot is realized by a drop in pitch on tones of the second foot, the shortened distance in (16b) can be realized by a rise in pitch on the tone of the first foot, i.e. a "raised" initial L.

The lack of phrase-initial tone terracing follows from the metrical account in a similar way. Since the pitch values of tones are relative to each other within the domain of an independent phonological phrase, every tone in phrase-initial position always belongs to the first foot, which receives the highest pitch within this phrase. The pitch of a phrase-initial tone always serves as the reference point to define terracing, in other words. A phrase-initial downdrift would simply make no sense. Can a downstep (i.e. a floating L) occur phrase-initially? Such a situation is possible, given no special reason why it cannot. However, if the floating L is followed by a H, the entire sequence will be of the form L H L H L ... just discussed. Suppose that such a sequence does exist, then the H following the initial L will be a phrase-initial downstep H on the surface. But such a case of terracing is often realized as a "raised" initial L. Since in this case the raised initial L is phonetically empty, no effect of a phrase-initial downstep H is observed. The occurrence of a floating tone or downstep is allowed everywhere, in other words, but its effects are neutralized in phrase-initial position, given our metrical system.[6]

As for the last two properties of tone terracing, they fall out as consequences of our assumption that downdrift and downstep share essentially the same set of rules: (4a), (4c), (6a), and (6b). The only difference is that while downdrift involves (4b), downstep involves (11), with each of their specific conditions on application. Thus, the amount of drop per instance of downdrift is exactly the same as that per instance of downstep, because the output of the foot formation rule (4b) and that of (11) are assumed to be both tonal feet, which are indistinguishably subject to the rules of pitch assignment.

Finally, the non-occurrence of downstep H after L in a sequence that also undergoes downdrift follows from our assumption that both downstep and downdrift involve the creation of a tonal foot on a H tone right after a L, though downstep involves the further condition that the L is a floating tone. (Only floating Ls trigger downstep, but all Ls may trigger downdrift.) Note that there is no special reason why a floating L tone cannot occur immediately before a H and immediately after a non-floating L. In such a situation we have a sequence of the form ... L ! H ..., where ! stands for a floating L. The existence of the ! would trigger the rule (11), which would assign the following H to an independent foot. But note that even if the ! were not there, the H would still be assigned to an independent foot, i.e. by the downdrift rule (4b), since it would still be immediately preceded by a L (in this case the non-floating L). Thus, again, the occurrence of downstep H after L is in principle allowed, but its surface effects are always neutralized.[7] Given that the effect of downdrift is transparent (observable from context), but the effect of downstep opaque, it is usually claimed that downstep H never occurs after L.

The explanation offered for the superficial non-occurrence of downstep H receives considerable support from the fact that this observation holds true only in sequences which also undergo downdrift. If a sequence does not undergo downdrift, then the effect of a downstep H after a non-floating L will not be neutralized, and its occurrence should be observable. This is indeed the case. For example, Hyman and Tadadjeu (1976) have shown that, in Dschang-Bamileke, only downstep but no downdrift occurs. It is precisely in this language that they also observe the occurrence of downstep H after L. The second of the following examples shows a downstepped H after L (Hyman 1979:11):

(17) a. [L H] àpá 'lid'

b. [L !H] àpá 'taro'

That the second syllable of 'taro' is associated with a downstepped H and not a mid tone is evidenced by the ceiling it establishes, limiting a following underlying H to an equal pitch height:[8]

(18) a. [L H $\neq$ H] àpá sáŋ 'the lid of the bird'

[L !H $\neq$ H] àpá sáŋ 'the taro of the bird'

Other examples supporting this account of the non-occurrence of downstep H after L are also available. Since downdrift occurs generally only in declaratives but downstep may occur in all sentence types, an otherwise neutralized downstep H after L may often be observed in a non-declarative sentence of a downdrift language, as for example in Igbo (John Goldsmith, personal communication).

5. COMPARISON WITH ALTERNATIVE TREATMENTS

I have outlined the basics of an autosegmental and metrical system of representation of downdrift and downstep, and shown how the well known properties of these processes may be naturally derived within such a system. It is appropriate to consider now some previous attempts and see how the present theory may be said to represent an improvement over them.

One type of representation that has been proposed in the literature is exemplified in such works as Fromkin (1972), Peters (1973), Clifton (1976). Fromkin suggests that the surface values of terraced tone patterns may be determined by rules which assign integers to lexically specified binary features. Specifically, she proposes to assign the pitch values 1 and 3 respectively to all H and L tones by the rule (19), and account for downdrift and downstep by (20), applied iteratively from left to right after (19):

(19) a. $[+H] \rightarrow p\ 1$

$[-H] \rightarrow p\ 3$

(20) $$[\alpha H] \rightarrow [\alpha H\ p\langle +1\rangle_{a,b}] / \begin{bmatrix}\alpha H\ p \\ \langle -Mid\rangle_a\end{bmatrix} \langle [-\alpha H]_1 \rangle_b \begin{bmatrix}\overline{\quad} \\ \langle +Mid\rangle_a\end{bmatrix}$$

(where the feature matrix [+H, +Mid] designates a downstep H, and *p* abbreviates "pitch"). Rule (20) expands into the six in (21):

(21) a. $[+H] \rightarrow [+H\ p{+}1] / \begin{bmatrix}+H\ p \\ -Mid\end{bmatrix} \begin{bmatrix}\overline{\quad} \\ +Mid\end{bmatrix}$

b. $[+H] \rightarrow [+H\ p{+}1] / [+H\ p][-H]_1 \underline{\quad\quad}$

c. $[+H] \rightarrow [+H\ p] / [+H\ p] \underline{\quad\quad}$

d. $[-H] \rightarrow [-H\ p{+}1] / \begin{bmatrix}-H\ p \\ -Mid\end{bmatrix} \begin{bmatrix}\overline{\quad} \\ +Mid\end{bmatrix}$

e. $[-H] \rightarrow [-H\ p{+}1] / [-H\ p][+H]_1 \underline{\quad\quad}$

f. $[-H] \rightarrow [-H\ p] / [-H\ p] \underline{\quad\quad}$

As an example, the same Akan sentence (1) is derived in the following manner:

/me-de-me-n-ma-m-fo-no-ba-a-me-fi/

L	L	H	H	L	L	L	H	H	L	H	L	
		1	1				1	1		1		by (19a)
3	3			3	3	3			3		3	(19b)
				4								(21e)
					4	4						(21f)
							2					(21b)
								2				(21c)
									5			(21e)
										3		(21b)
											6	(21e)
3	3	1	1	4	4	4	2	2	5	3	6	Output

The rules (21c) and (21f) ensure that no pitch lowering occurs between identical tones. (21b) and (21e) jointly account for downdrift: the former lowers the pitch of a H by one step from the pitch of a preceding H when these two Hs are intervened by an arbitrary sequence of Ls; and the latter lowers the pitch of a L by one step from the pitch of a preceding L when these two Ls are intervened by an arbitrary sequence of Hs. The rule (21a) accounts for downstep: it says that any a [+H, +Mid] (a H marked for downstep), when occurring immediately after another H, lowers its pitch by one step from the pitch of the preceding H. The rule (21d) says that a [-H, +Mid] lowers its pitch by one step from the preceding L when immediately preceded by another L. This last rule is never realized, however, since the system does not have any [-H, +Mid] or downstep Ls.

It is important to note that, in this type of representation, no distinction is made between the level of tone and that of the pitch register. As such, the Fromkin-type theory is mixed-level, non-autosegmental system. Furthermore, as the system makes crucial use of integers, it is not a metrical system. Let us first concentrate on the non-autosegmental nature of the system. There are a number of drawbacks to any theory having this nature.

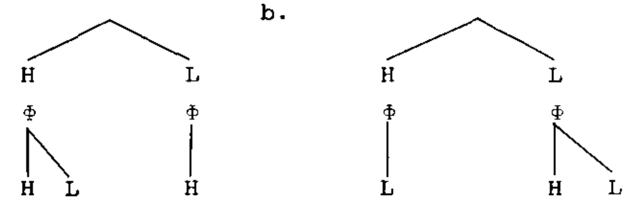
First of all, the properties that, as we observed, seem to suggest that matters of tone and matters of pitch register are distinct, do not receive a natural interpretation. For example, the preservation of tonal contrasts by terracing is accounted for in this system as the result of the stipulated application of two different rules. In particular, just in case a H lowers its pitch by the rule (21b), a following L must also lower its pitch, this time by a different rule, (21e). This result is ensured by the requirement that both rules exist and one of them apply if and only if the other does also. Such a stipulation misses a generalization. Furthermore, if the system fails to include a rule lowering the pitch value of a L according to each rule lowering the pitch value of a preceding H, the system will be empirically inadequate. There is indeed an empirical failure of precisely this type in Fromkin's system, as observed by Peters (1973). More specifically, although Fromkin provides the rule (21a) to account for the pitch value for a downstep H, she does not have a rule that lowers a L following the downstep. The rule (21d), as just mentioned, is never realized. While this empirical failure can be corrected, as is done in Peters (1973) for example, the important point is that the system remains essentially stipulative in nature. In the autosegmental theory, preservation of tonal contrasts is a natural consequence of the postulation that terracing affects pitch-bearing units as a whole, without altering the internal relationship between tones within a given foot.

Another indication of this conceptual problem in the mixed-level system is that the amount of pitch drop per instance of downdrift or downstep is ensured to be less than the distance between contrasting tones by requiring the initial rules (19) to assign 1 and 3 respectively to H and L, and the rules in (21) to each assign at most 1 pitch increment at one time, again by stipulation. There is no clear indication why the (19) and (21) should assign different values of pitch. Within the autosegmental approach, the non-equality between contrasts in the tonal level and those in the registral level are natural consequences of the fact that these two levels are autonomous.

A second defect of the type of system proposed by Fromkin is that a sequence of the form H L H undergoes a different rule than a sequence of the form L H L, and the phenomenon of downdrift that happens in them seems to receive two different interpretations. In the former case, the second H lowers its pitch after a preceding L. This

might be interpreted as a process of assimilation (vertical assimilation in the sense of Hyman 1973). In the latter case, the second L lowers its pitch after a preceding H. This process certainly is not one of assimilation, and it is not entirely clear what it is (perhaps a process of disimilation?) Within our system, both instances receive a uniform interpretation. The two sequences have the following forms:

(22) a. b.



These two sequences are organized in different ways in the tonal level, but look identical in the registral level. Since downdrift affects only the registral level, the two sequences above receive a uniform interpretation: register lowering occurs on both their second pitch-bearing units.

A third problem with the mixed-level system is its obvious complexity. In our theory, we "modularize" the grammar into two autonomous components, and obtain the desired results of terracing by relatively simple rules, such as the two rules of (6). This result seems to be conceptually more desirable, and is in accordance with recent advances in syntactic theory, represented in, say, the modular framework of "Government and Binding" (Chomsky 1981).

Other objections to the type of system represented by Fromkin (1972) have been separately raised elsewhere, for example in Clements (1979), who also points out, among other things, the strange character of the iterative rules proposed, as well as the non-universal character of the system. In a system of the sort proposed by Clements (1979) and partially followed in Hyman (1979), there is a formalism that characterizes terracing somewhat independently of tonal patterns. Clements proposes that the tones of a given language are organized into a set of formal objects that he called "tone level frames." Each tone-level frame consists of "a set of n tone levels ordered under the relation '>' ('higher than'), and a set of n-1 intervals," which are "relations holding between neighboring tone levels, that is, tone levels which are consecutive in the ordering established by the relation 'higher than' (p. 547-48)." For example, in a sequence of the form H L H L H L H, each tone is projected onto either the level H or L of the tone level frame. The intonational pattern of the entire sequence is then characterized in terms of these tone-level frames. Each tone-level frame "does not constitute a set of absolute acoustic parameters. Rather it is subject to modification as a result of the intonational processes that apply to it. The identity of the frame itself, however, is not affected by these modifications (p. 549)."

For each individual language, the internal structure of each tone level frame, e.g. the interval between two tone levels within each frame must be specified. For a two-tone terraced-level language, for example, Clements suggests that the interval may be arbitrarily set at *2* (pitch increments). By convention, an initial H is designated as 1 and an initial L as 3. To derive the correct pitch representation of a sentence involving terracing, Clements further suggests marking downstep by a ! symbol preceding the downstepped tone, and incorporates downdrift with downstep by a rule that introduces a ! in the environment H___L:

(23) $\emptyset \rightarrow$! / H___L

The mark ! (either underlying or introduced by (23)) is treated as an abstracting rule-triggering segment on the tonal level, whose function is to induce pitch lowering:

(24) $T_Q \rightarrow$ +1 pitch / H !___

which assigns one pitch increment to every maximal string of tones (T_Q) following any ! immediately preceded by H. The final output is obtained by adding up all increments assigned to each tone. A sample derivation is given below:[9]

(25)	aberanteɛ	bɛkɔ	ɛhɔ	
	L L H !HH	H H	L H	(lexical representation)
	L L H !HH	H H	!L H	(23)
	3 3 1 11	1 1	3 1	(initial assignment)
	11	1 1	1 1	(24)
			1 1	(24)
	3 3 1 22	2 2	5 3	Output

It should be apparent that Clements' tone level frames are intended to have the effect of maintaining the autonomy of a tonal level - in a way similar to the effect of our pitch-bearing unit or tonal foot. Our representation appears to be clearer, however, in that it directly reflects the autonomy of the tonal level by having tones of the same foot dominated by a node whose internal structure is inaccessible to rules of a higher level.[10]

A more important difference between Clements' system and the system proposed here, is that the former makes crucial use of integers, and is thus non-metrical in nature. In this respect, Clements' system is more like Fromkin's. There are also a number of drawbacks to the non-metrical theory.

First, as Liberman and Prince (1977) have argued, stress values have meaning only in relation to each other. Likewise, the assignment of an initial L as *+3* is meaningless when taken alone. Furthermore, an integer system involving multi-valued features like [+7 pitch] etc. is quite complex and theoretically undesirable, especially in view of the fact that other aspects of phonology can be captured within a theoretically much more simple framework employing only binary features. In other words, instead of a complex multi-valued system, it is theoretically desirable to modularize it into an indefinite number of levels of representation, within which every node is binary branching and describable in terms of a simple [+H] vs. [-H] feature system.

Secondly, a non-metrical system makes its own scope of application too narrow to provide a general description of the terracing phenomena across variations of the sort noted above. For example, the stipulation that an initial H is assigned 1 and an initial L assigned 3 pitch increments is only suitable for languages or sitations in which each instance of terracing involves the drop of pitch half the size of the contrast between underlying contrasting tones. Such a system cannot be extended to languages involving "tonal downstep" (cf. footnote 1). It is probably also too narrow to be applicable across different speech situations within a speaker's idiolect, given that speakers vary the amount of pitch lowering depending upon utterance length, as noted above.

Thirdly, the lack of phrase-initial terracing, which is naturally attributed to the relational nature of tone and pitch within our metrical system, is not derivable without some sort of stipulation or other in Clements' system. Suppose there is a phrase-initial ! in some sequence. The fact that this initial ! will not have a surface pitch-lowering effect is ensured by the stipulation in the rule (24) that a ! induces pitch lowering only when it immediately follows a H. Similarly, in Fromkin's system, this fact is ensured by a stipulation that every case of downstep H (her [+H, +Mid]) induces pitch lowering only when there is an immediately preceding H, as is indicated in her rule (21a). The stipulative nature of both accounts is obvious.

Finally, the difference in realization and perception between sequences of the form H L H L H ... and those of the form L H L H L ... is again not derivable without some stipulation. As we shall see shortly, Clements' rule (23) should be revised as follows, in order to derive the lack of downstep H after L in a sequence involving downdrift:

(26) $\emptyset \Rightarrow$! / L__H

(This is, in fact, the rule adopted in Hyman 1979.) If this is the case, then there will be a ! immediately before the first H tone of the sequence of (25) above, or of any sequence of the form L H L H L ... If each ! induces one drop in pitch, then the tone with the highest pitch in (25) or in any sequence of the form L H L H L ... will be assigned the pitch value *2*. But this will imply that an independent phonological phrase of this form *must* always be pronounced at a pitch level one step lower than any phonological phrase of the form H L H L H ..., where the first H is assigned the pitch value *1*. This does not seem to be correct, as one can tell from the integer transcription that Clements has given for (25), where the first H is assigned the value *1*, and from the transcription Fromkin has assigned to the Akan example, where the first H also has the value *1*. (But cf. footnote 6. Recall also the definition of downdrift given by Armstrong (1968: 51), which says that only *non-initial low* tones have the effect of inducing pitch lowering on following tones.) In order not to obtain the value *2* for the first H within a system that incorporates (26), it is necessary to stipulate somehow that the leftmost H in any sequence is not subject ot pitch lowering regardless of whether there is a preceding !.

There is one more point to be mentioned in comparing our system of representation to the ones represented by Fromkin (1972) and Clements (1979). This has to do with the lack of downstep H after L in a sequence that also undergoes downdrift. This fact is easily derived as a case of neutralization in our system, but not so in either Clements' or Fromkin's. In the latter two systems, the result is obtained again through a stipulation. According to Fromkin, this is obtained by stipulating that the rule (21a) apply only when there is a H immediately preceding the downstep H. In Clements' system incorporating (23), the effect of an underlying downstep H immediately following a L also cannot be neutralized without stipulation.

Such a sequence would have the form H L ! H ... After the rule (23) applies, the sequence will be turned into the form H ! L ! H ..., with two !s, one preceding and one following the L. The second ! thus cannot be neutralized by the first !. In order to obtain the fact that there is no downstep H after L, it is therefore necessary to stipulate, again, that the second ! here does not induce pitch lowering. Precisely this stipulation is contained in the rule (24), which requires that the tone preceding ! must be H in order for the rule to apply. The only way to avoid this stipulation in this system would be to assume the rule (26) instead of (23), as Hyman (1979) has done. In this case, a downstep H after L will occur in a sequence having the underlying form H L ! H ... Since this is also the form one will get by applying (26) even in the absence of the underlying !, the surface effect of this underlying ! is neutralized in this position. This, however, brings one back to the problem just mentioned in the immediately preceding paragraph.

6. REFINEMENTS AND EXTENSIONS.

We have seen sufficient reason, I think, for the belief that a modular system of the sort developed in this paper qualifies as a more nearly adequate system of mental representation. We have been concerned throughout, however, only with fairly well known examples of downdrift and downstep. In order to qualify as an adequate general theory of terracing, the system must also be capable of accounting for examples of upstep and upsweep, as well as other less well known, more complicated cases of downdrift and downstep. In this concluding section I will outline some of the possible extensions and refinements of this system which may be made to accommodate these latter cases.

First of all, the occurrence of upstep and upsweep cannot be accommodated readily within the present system without some refinements. A close look at the nature of our rules reveals that what we need to do is replace the rules in (6) with their mirror image:

(27) a. Construct a left-branching tree over a sequence of tonal feet.

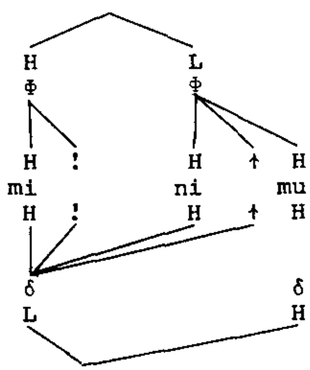
b. Given two sister nodes N_1 and N_2, label N_2 as L iff it branches.

All the other rules suggested earlier may remain applicable, A further modification that has to be made is that the tonal feet formed for upstep or upsweep must be formally distinguishable from those formed for downdrift and downstep, so that one may apply (6) or (27) properly. Furthermore, since it often happens that a sequence may contain instances of both downstep and upstep, it will be necessary to represent the two types of terracing by two trees. The following example is taken from Hyman (1979:12):

(28) mi ni mu 'my water'
H !H ↑H
[‾ - ‾]

The last H is marked as being upstepped. Since it is preceded by a downstepped H, the effect of the upstep is to bring the pitch of the following H back to the height of the first H. In the following representation, the upper tree accounts for downstep, and the lower tree for upstep:

(29)



If the amount of pitch drop per instance of upstep is equal to that per instance of downstep, then an overall evaluation of the two trees in (29) may be interpreted as representing all the relevant information contained in (28). Whether or not this is entirely correct remains yet to be seen, against a wider range of data on upward terracing, comparatively little of which has been reported in the literature.[11]

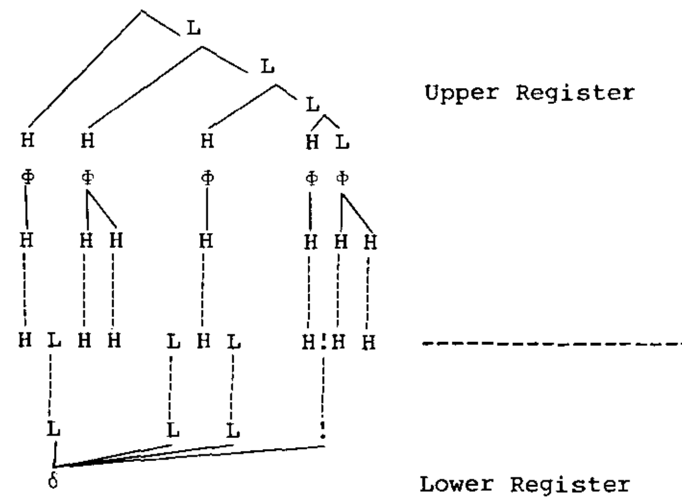
Another area which may call for some refinement of the system concerns languages in which downdrift occurs only to Hs in a sequence of alternating Hs and Ls, while the Ls remain constant at a rock-bottom low level of pitch. For example, ignoring the effect of an upstep element, the ShiTswa sentence (30) is reported in Welmers (1973:92) as having the surface form (31), where all the Ls are realized on a constant low level:

(30) H L H H L H L H!H H
vamuwona mufana wahosi

(31)

Suppose that Welmers' transcription is correct.[12] The generalization here, it seems, is that Hs and Ls may behave differently in some languages with respect to pitch assignment. For such languages, I suggest a bifurcation of the pitch-register in the following manner. First (4b) applies to assign the second, fourth, and fifth Hs each to an independent foot node, and (11) assigns the sixth H to another foot. Then all Hs are projected to one register and all Ls are projected to a different non-overlapping register. These will be called the upper and the lower register, borrowing the terms from traditional discussions of tonogenesis. In this way, all tones that are assigned to the beginning of a foot are in the upper register. After (4a) and (4c) apply, we obtain the following representation, corresponding to (31):

(32)



The postulation of two separate registers in the way suggested makes certain interesting claims. It also offers an interesting analysis of the tone patterns of three-tone languages such as Ikom-Yala (Armstrong 1968) and Ga'anda (Newman 1971), which exhibit both downdrift and downstep. I will illustrate with Ikom.

In Armstrong (1968), it is reported that Ikom has three underlying tones H, M, and L; and further that every H downsteps after a M or a L, and every M downsteps after a L. Such a situation would seem easy to handle by generalizing the rules in (4b) so that every tone occurring after a lower tone gets assigned to a new foot. However, the situation is more complex. Consider a sequence like (33), where two Hs are intervened by a sequence of Ms and Ls that also meet the requirement for downdrift/ downstep:

(33) H H M !M M L H
ɔ kpacɔ !agɔ !otu
'He put stones in holes at night.'

A theory using only one register will predict that the last H will step down twice, once due to its occurrence after a L and once due to the downstep of a preceding M. However, as has been brought to my attention by Barry Schein (personal communication), the transcription given by Armstrong shows that the H steps down only once. This suggests that Hs and Ms behave quite independently of each other with respect to terracing. The problem may be settled in the following way. After (4b) applies to assign the last H to an independent foot, project all Hs to the upper register and all the non-Hs to the lower register. In the upper register, then, the last H will step down only once, in accordance with Armstrong's report.

If the analysis suggested in this final case is correct, note that there is at most a two-way contrast within each register, so that in the lower register M may be set in contrast with L by the single parameter [αH]. By modularizing pitch registers into two components, a three-way tonal contrast may be reduced to a more simple binary system of tonal features. This result again seems to be desirable, and is consistent with the already highly modular character of the grammar we assume.[13]

FOOTNOTES

* This paper is a revised and expanded version of a paper delivered at the 10th Annual Conference of the North Eastern Linguistic Society. An abbreviated version appeared in the proceedings of the conference. I am grateful to Morris Halle, Nick Clements, Larry Hyman, John Goldsmith, Ken Hale, Jay Keyser, Paul Kiparsky, and Moira Yip for insightful comments on various earlier versions of the paper.

1. In some rare cases, the drop occurring in terracing may equal the distance between contrasting tones. Such cases are termed "total downsteps" in Clements and Ford (1979).

2. The correctness of this claim is to some extent controversial, but I think it is essentially correct. See footnote 6 for additional comments.

3. See, for example, Peters (1973:141). Hyman (1979:16), on the other hand, proposes that the downstep in the example is developed from a process of tonal simplification, by which a falling tone followed by H is simplified to a sequence of two level tones: H followed by downstepped H.

4. Thus, it is not correct to say that the position of occurrence of downstep is unpredictable. It is only unpredictable from the surface observable sequence of tones.

5. Although the rule (11) looks very similar to (4b), they must be kept apart, since the two rules are different in scope of application, as will be indicated below.

6. Hyman (personal communication) has indicated that some cases of phrase-initial downstep may acually be observed on the surface, and not necessarily neutralized, though he also mentions that this is only optional. He also indicates that in a sequence of the sort L H ..., the H can be heard as distinctively lower than a non-downstepped H uttered in isolation. These remarks contradict the observations that I have held true, based upon remarks made by other writers (e.g. Armstrong 1968, Peters 1973, etc.) However, I prefer to interpret his facts as indicating that speakers may utter such sequences in comparison with some basic reference point established in other phonological phrases. In such situations, these phrases may be re-

garded as non-independent phonological phrases in some sense. Judging from the conflicting reports, it seems that at least it is possible (though not necessary) to pronounce any such initial Hs at a level that is normally used for non-downstepped Hs, especially when such phrases are pronounced in absolute isolation (i.e. without any preceding or following utterances pronounced within the same speech situation). The same situation happens also with stress systems. For example, one may pronounce the English article *the* with or without stress in isolation. Furthermore, the stress of *long* in *Long Island* may be perceived to be distinctively weaker in stress (tertiary) than the *long* in *a long island* (secondary), even when both are uttered in isolation. These facts, it seems, should not be taken to invalidate the claim that stress, pitch, and tone are essentially relational in nature.

7. The interpretation of this fact as a case of neutralization has been proposed quite early, in Schachter (1961), though no previous system of formal representation, to my knowledge, has accounted for it without some degree of stipulation.

8. The downstepped H in the second example may be perceived as lower than the non-downstepped H in the first example, if the initial L is kept at the same pitch height in both examples. If the downstepped H in the second example is as high as the H in the first example, there will be a "raised" initial L in the second example. Cf. footnote 6 above.

9. The penultimate vowel in this example will have to be deleted before the final output is obtained.

10. It should be noted that Clements' (1979) paper does not reflect his current thinking in its entirety. Therefore the discussion that follows in this section does not apply to his current view. In his more recent paper (Clements 1981), he has independently developed a metrical theory that is similar to ours in many ways. A discussion in this section of his earlier theory is worthwhile, however, and through this discussion I believe that an argument can be made for the view that we now share.

11. For an alternative treatment of upsteps, see Clements (1981).

12. Hyman has informed me that there is some disagreement over whether Welmers' transcription is entirely correct. The controversy is either over (a) whether it is possible for Hs to downdrift without Ls also doing so; or (b) whether there is not some systematic difference between the two kinds of downdrifting. We tentatively assume that the answer to these two questions is yes.

13. This result is also consistent with the theory of tone features developed in Yip (1980). Yip provides the two parameters [αH (tone)] and [&Upper (register)] to characterize all tones of languages. A conception about the independent nature of each of the parameters is shown to play an important role in the analysis of tones in several Chinese dialects.

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