Phonological Features of Tone

1.1 General Discussion

'Tone languages',\(^1\) in a broad sense, are found in most parts of the world. In examining the literature on languages of this type, our attention is particularly drawn to three linguistic areas: (i) certain clusters of American Indian languages, (ii) the vast majority of African languages, and (iii) almost all of the languages of the Sino-Tibetan family together with many neighboring languages of Southeast Asia. Typically, tone systems of areas (i) and (ii) differ from those of area (iii) in several ways.

One point of difference is in the use to which tones are put. In languages of area (iii), tones are almost exclusively used lexically, with no correlation with the syntactic or morphological aspects of the language. There are exceptions, of course, such as the breathy fall-rise tone in Vietnamese which is "sometimes used anaphorically to refer back to some 'key' noun or nominal expression in what has gone before,"\(^2\) or the modified tones in several Chinese dialects which serve a variety of connotative as well as minor syntactic function.\(^3\) Indeed, in the Peking dialect there are two dozen or so morphemes which change grammatical category according to tone. But these uses are marginal when they are compared to the extensive load that tones carry in the declensional and conjunctational morphology of many languages in America and Africa, as exemplified in sections 3.11.2 and 3.11.3 of Nida's Morphology,\(^4\) and documented abundantly in the literature which deals with these languages.\(^5\)

The tone paradigms of languages of area (iii) are typically more complex. If we count each distinct pitch shape in citation monosyllables as a tone, then paradigms of 6 or 7 tones are quite common. According to a recent study, Cantonese may have as many as 10 tones.\(^6\) On the other hand, although a few American Indian languages also appear to have complex paradigms, languages of areas (i) and (ii) in general do not have as many distinct shapes. Most languages of these two areas have simply two or three noncontour tones; a relatively small number of these languages have contour tones in addition.\(^7\)

Yet another point of difference can be seen in the way tone sandhi operates. The sequence of tones in many Bantu languages, for example, undergoes a form of sandhi that is essentially by syntagmatic displacement, i.e., a kind of tonal 'musical chairs' in

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which each syllable receives its tone from its (usually left) neighbor. The sandhi in the so-called terrace-level tone languages of West Africa is also syntagmatic in the sense that the pitch value of an unaccented syllable is usually predicted from the pitch value of the left neighbor. Tone sandhi in languages of area (iii), however, is by paradigmatic replacement. Characteristically, tone \(x\) is replaced by tone \(y\) when it is within some linguistic environment, and it is irrelevant whether tone \(y\) is present elsewhere in the sequence of tones. Frequently the phonological environment in which tone \(x\) occurs is also irrelevant for the sandhi. Some very complex situations of paradigmatic sandhi are found in the Min and Wu dialects of Chinese, an example of which is given in 1.8 of this paper.

### 1.2 Tone Features and Segmental Features

Recently I have examined a large number of tone languages, mostly of area (iii), with a view towards constructing a set of phonological features of tone. These features are proposed here as an addition to a general theory of phonology. They are designed to complement the two dozen or so features which are currently used in the phonological classification of segmental sounds.

Tone features, of course, are not completely independent of the segmental features. They have a particularly close relation, synchronically and diachronically, with features which are controlled primarily at the larynx, e.g. voicing, aspiration, glottalization, length, breathiness, etc. This relation is easily understandable since the primary determinant of tone is the rate of laryngeal vibration.

Indeed the development of some types of tonal distinctions probably can be explained in terms of oppositions which are originally segmental. As an example, although Middle Chinese (ca. 600 A.D.) is traditionally regarded as having four distinct tones, from physiological considerations we know that it must have had eight pitch shapes. Four lower-pitch ones appeared only with syllables with voiced initials, the remaining only with unvoiced initials. The phonetic difference between the four pairs of pitch shapes is intrinsic in that it can be predicted from the mechanical properties of the speech mechanism. Like the pitch difference between English /pin/ and /bin/ it is not phonemic even though it is perceptually quite noticeable. When the voicing distinction was obliterated through historical change, as evidenced in most Chinese dialects today, the phonetic differences in the pitch shapes in certain cases became distinctive.

It is more difficult to provide a phonetic motivation for the extrinsic relationship that has been observed between tones and vowel height. This is reported to exist subphonemically in Peking Chinese, where certain mid vowels have a lower articulation with two of the four tones. Much more striking, however, are the morphophonemic alternations in Foochow Chinese, where whole sets of the vowels are raised and diphthongs monophthongized when certain tone sandhi rules are applied.
In languages like Chinese the tone features are sometimes relevant for the initial consonant, sometimes for the nuclear vowel, and sometimes for the final consonant in various phonological rules. If we were to add a column of tone features to a phonological matrix of segmental features, then it becomes arbitrary where precisely to insert this column. Furthermore, segmental features are usually not relevant in the various types of tone sandhi; that is to say, the interaction of tones in a sequence is independent of the nature of the segments which occur with the tones. Phonetically, of course, the domain of the tone is over the entire voiced portion of the syllable. From these considerations, it is preferable to formalize the tone features differently from the segmental features and regard them as features of individual syllables. In Chinese, this is almost equivalent to marking these features on individual morphemes since almost all morphemes can be represented as single phonological syllables. For languages with many polysyllabic morphemes, it appears that the syllable may need to be given independent theoretical status in order for it to bear the phonological features of tone.

1.3 Presentation of Phonological Features

The features of tone, much as other phonological features, are selected for the dual purpose of (i) describing the alternations, both synchronic and diachronic, that are found in language, and (ii) providing the abstract linguistic basis from which physical phonetic interpretations are made. As a consequence of the lack of a perfect match between these two functions a universal set of phonological features usually contains a certain amount of internal redundancy in that some combinations of the feature specifications are not permitted in principle. Statements regarding permitted feature combinations are 'redundancy conventions'. The term 'convention' refers to language-universal statements while 'rule' refers to language-specific statements.

Of the permitted combinations of tone features, it appears from the languages examined that some combinations are favored over others, as is the case with segmental features. The present theory attempts to incorporate this aspect of tone systems by 'marking conventions', using the notion of 'markedness' as it has been recently refined by Halle and Chomsky. As will be seen in 1.7, this notion allows us to state in a precise way the relative complexity of different types of feature combinations. Within such a framework the combinations which tend to be favored are the ones which minimize the total complexity of the paradigm.

1.4 A Proposed Set of Tone Features

The rapid advances in physical phonetics during the past two decades have made it increasingly clear that there is frequently a considerable discrepancy between a linguist's phonetic interpretation of a speech wave and what the speech wave actually contains.
The parameter of voice pitch varies according to a variety of other factors\textsuperscript{15} (emotive ones like speaker’s mood and voice volume; cognitive ones like intonation, contrastive accent; intrinsic ones like tongue height and degree of supraglottal closure; etc.) What is said below about the phonetic value of the tone features must be understood as descriptions of idealized patterns distilled out of speech events rather than, say, what can be measured directly from narrow band spectrograms. Using the ‘tone letter’ notation proposed by Y. R. Chao,\textsuperscript{16} we present below an illustrative set of 13 tones as shown in Table 1, together with a set of seven features. Certain features which are primarily associated with segmental oppositions, such as the laryngeal ones mentioned above in 1.2, may also participate in distinguishing tones in phonological representations.

As can be seen from Table 1, the $-$CONTOUR tones (i.e. tones 1 through 5) are divided into five levels by the features HIGH, CENTRAL and MID. The $+$CONTOUR tones go either in one direction or in two directions; the former (i.e. tones 6 through 9) are either $+$RISING or $+$FALLING, while the latter (i.e. tones 10 through 13) are both $+$RISING and $+$FALLING. The bidirectional tones are further divided by the feature CONVEX.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONTOUR</td>
<td>$-$</td>
<td>$-$</td>
<td>$-$</td>
<td>$-$</td>
<td>$-$</td>
<td>$+$</td>
<td>$+$</td>
<td>$+$</td>
<td>$+$</td>
<td>$+$</td>
<td>$+$</td>
<td>$+$</td>
</tr>
<tr>
<td>HIGH</td>
<td>$+$</td>
<td>$+$</td>
<td>$+$</td>
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<td>$+$</td>
<td>$+$</td>
<td>$+$</td>
<td>$+$</td>
<td>$+$</td>
<td>$+$</td>
<td>$+$</td>
<td>$+$</td>
</tr>
<tr>
<td>CENTRAL</td>
<td>$-$</td>
<td>$-$</td>
<td>$+$</td>
<td>$+$</td>
<td>$+$</td>
<td>$+$</td>
<td>$+$</td>
<td>$+$</td>
<td>$+$</td>
<td>$+$</td>
<td>$+$</td>
<td>$+$</td>
</tr>
<tr>
<td>MID</td>
<td>$-$</td>
<td>$-$</td>
<td>$-$</td>
<td>$+$</td>
<td>$+$</td>
<td>$+$</td>
<td>$+$</td>
<td>$+$</td>
<td>$+$</td>
<td>$+$</td>
<td>$+$</td>
<td>$+$</td>
</tr>
<tr>
<td>RISING</td>
<td>$-$</td>
<td>$-$</td>
<td>$-$</td>
<td>$-$</td>
<td>$+$</td>
<td>$+$</td>
<td>$+$</td>
<td>$+$</td>
<td>$+$</td>
<td>$+$</td>
<td>$+$</td>
<td>$+$</td>
</tr>
<tr>
<td>FALLING</td>
<td>$-$</td>
<td>$-$</td>
<td>$-$</td>
<td>$-$</td>
<td>$-$</td>
<td>$+$</td>
<td>$+$</td>
<td>$+$</td>
<td>$+$</td>
<td>$+$</td>
<td>$+$</td>
<td>$+$</td>
</tr>
<tr>
<td>CONVEX</td>
<td>$-$</td>
<td>$-$</td>
<td>$-$</td>
<td>$-$</td>
<td>$-$</td>
<td>$-$</td>
<td>$-$</td>
<td>$-$</td>
<td>$+$</td>
<td>$+$</td>
<td>$+$</td>
<td>$+$</td>
</tr>
</tbody>
</table>

Although tones in some languages have been transcribed with as many as nine phonetic levels of pitch, I have not been able to find any language that has more than five distinctive pitch levels, which turns out to be exactly the maximum number that Chao allows for in his insightful notation. In fact, the only clear cases I know of where there are five distinctive pitch levels are some Black Miao languages recorded by Kun
Chang and by F.K. Li. These are the only languages, in other words, which exploit the feature MID of Table 1. According to Chang, the Yong-Gong language has a rising tone and two falling tones in addition to five level tones; the level tones may be exemplified by mo⁵ name, me⁴ eye, mjo³ ear, ko² road and mjo¹ fish. The Tai-Gong language has a falling tone and two rising tones; its level tones may be exemplified by la⁵ short, la⁴ classifier, la³ cave, la² to move away, and la¹ candle. In these examples, lower numbers indicate lower pitch levels.

The above observation on the number of levels is only valid, of course, if we recognize in some cases contour tones in the paradigm. Thus in Trique, only four phonemic levels (the tone features HIGH and CENTRAL) appear to be necessary, since the fifth level goes only with a contour tone which can be distinguished from the level tones by some other feature. The recognition of contour tones is crucial in the analysis of certain types of tone systems if we are to capture all and only the consistent characteristics in the phonological structure. If it turns out that FALLING is the only relevant feature for a particular tone, then over-differentiation would only lead to chaos when we try to mark what pitch level the tone falls from or what level it falls to. This would be like trying to mark, say, seven degrees of aspiration for English stop consonants. As Gleason remarked in connection with Doke’s attempt to describe Zulu tones with nine levels, “the phonemic contrasts in the pitch system involve other dimensions than mere level”; it comes as no surprise that the nine-level system of transcription proved ‘utterly impossible to teach to Zulu students’. Doke’s case of nine pitch levels provides a rather extreme example of phonetics running wild in the absence of theoretic constraint. Nonetheless, I suspect that many tone descriptions of the languages of areas (i) and (ii) can be re-examined with profit to see if new regularities can be discovered when contour tones are added to the paradigm.

Related to the difficulties due to over-differentiation within single tone paradigms is the situation we encounter when we compare tones of different paradigms or different reports on the same tone paradigm. Here again the crucial step is to separate phonetic differences which are distinctive from those which reflect non-distinctive variations within or between speakers, or the habits of the phoneticians who made the transcription. Consider, for example, the data on the first eight sites reported in the dialect survey of Jiangsu. For each site the values for the four lexical tones, originally given in Chao’s tone letters, are presented below in numerical form:

<table>
<thead>
<tr>
<th>Site</th>
<th>Tone</th>
<th>Value 1</th>
<th>Value 2</th>
<th>Value 3</th>
<th>Value 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>213</td>
<td>55</td>
<td>35</td>
<td>52</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>212</td>
<td>55</td>
<td>35</td>
<td>52</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>313</td>
<td>55</td>
<td>35</td>
<td>51</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>313</td>
<td>55</td>
<td>24</td>
<td>51</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>313</td>
<td>55</td>
<td>24</td>
<td>52</td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>213</td>
<td>54</td>
<td>24</td>
<td>52</td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>213</td>
<td>55</td>
<td>24</td>
<td>51</td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td>213</td>
<td>55</td>
<td>24</td>
<td>42</td>
<td></td>
</tr>
</tbody>
</table>
Let us consider the above data in conjunction with the tones reported for Suzhou, site number 34 covered by the Jiangsu survey. Line 9 gives the values of the Suzhou tones according to the survey. Line 10 gives the tone values as they are reported in another recent source:

<table>
<thead>
<tr>
<th>9</th>
<th>44</th>
<th>13</th>
<th>52</th>
<th>412</th>
<th>31</th>
<th>5</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>44</td>
<td>24</td>
<td>41</td>
<td>513</td>
<td>331</td>
<td>4</td>
<td>23</td>
</tr>
</tbody>
</table>

The lesson from the above data is quite clear. It is evident from the values given in lines 1 through 8 that these sites have the same four tone paradigm, which can be distinguished by the same two features, i.e. FALLING and RISING. The only point that is somewhat uncertain is that the second tone of site 6 is reported to fall slightly, whereas we are interpreting it here to be -FALLING. The variations 213/212/313, 35/24 and 52/51/42 are obviously nondistinctive for any purpose, and are probably more spurious than real. This overdifferentiation is due to a notational device which, in order to be universally applicable, must provide for more distinctions than any single paradigm can have. (In fact, the tone letters allow for 5 pitch levels at each of three positions, or a total of 125 tones.)

Our line of reasoning is strengthened when we examine lines 9 and 10 above. This kind of discrepancy between different reports on the same site is not uncommon in the literature on Chinese dialects. Here we find the same type of variation that in all likelihood does not represent any consistent or systematic property of Suzhou speech. Whether the seventh tone in this dialect (which is a short tone) rises or not is a matter that needs more refined phonetic study. As for the difference between the two reports on the fifth tone, the system of phonological features proposed here would predict it to be nondistinctive in principle: 331 is just a slowed down 31. Again, we would assume that lines 9 and 10 represent an identical tone paradigm in spite of the phonetic differences reported for almost each of the seven tones.

1.5 Redundancy Conventions

In principle, seven binary features can distinguish 128 objects. Since we are making use of only 13 tones in connection with these features, the redundancy is considerable. This redundancy can be formalized in conventions which predict certain combinations of feature specifications to occur while prohibiting other combinations from occurring. Of the total set of redundancy conventions that can be stated in a general theory of phonology, only a subset is relevant for any particular tone paradigm. This relevant set is determined by which features in the paradigm are considered to be lexically distinctive in the language.
To illustrate this point, let us refer back to Table 1. Let us make the unlikely assumption that all the feature specifications enclosed by the dotted lines are distinctive, hence yielding a paradigm of 13 tones. Given these feature specifications, all of the remaining feature specifications of Table 1 can be predicted by the following redundancy conventions:

1. \([-\text{CONTOUR}] \rightarrow [-\text{RISING}]
   \quad [-\text{FALLING}]
   \quad [-\text{CONVEX}]

2. \([+\text{HIGH}]\)
   \quad \([-\text{CENTRAL}]\)
   \rightarrow \([-\text{MID}]

3. \([+\text{CENTRAL}]\)
   \rightarrow \([-\text{CONTOUR}]

4. \([+\text{RISING}]\)
   \quad \([-\text{FALLING}]\)
   \rightarrow \([-\text{MID}]

5. \([-\text{CONTOUR}]\)
   \rightarrow \([-\text{CENTRAL}]
   \quad [-\text{MID}]

6. \([-\text{RISING}]\)
   \quad \([-\text{FALLING}]\)
   \rightarrow \([-\text{CONVEX}]

The redundancy that is embodied in the system of tone features is of three types. First there is the type that follows directly from the phonetic meaning of the features; this type of redundancy can be exemplified by convention 1 above. Secondly, redundancy arises when we make empirical claims about what distinctions are actually used in lexical representations at the systematic phonemic level. For instance, while we allow five pitch levels to be distinctive for \(-\text{CONTOUR}\) tones we are only allowing two pitch levels to be distinctive for \(+\text{CONTOUR}\) tones, as can be seen from convention 5. Such restrictions can always be removed when counter-evidence becomes available.

A third type of redundancy comes from the fact that an identical set of tones may alternate differently in different phonological systems, a possibility that was high-lighted in the writings of Edward Sapir. This means that a phonological theory must be able to provide alternative feature representations for the same sounds as those sounds ‘configure’ differently from language to language. Thus if \([n]\) alternates with liquids in one language and with stop consonants in another, then it should have different underlying representations in the two languages. These considerations lead us to posit the three features \text{CONTOUR}, \text{FALLING}, and \text{RISING}, even though no paradigm would ever use all three of these. For the purpose of describing tone alternations, this particular redundancy is essential.

To illustrate, let us take three tones which have roughly the values of tones 1, 6, and 8 in Table 1. Tones of these values occur in the Chinese dialects of Peking,\(^{24}\) Canton,\(^{25}\) and Chaozhou\(^{26}\) together with other tones. But the behavior of these tones in the three dialects is quite different. In Peking tone 1 alternates with 6; in Chaozhou 6 alternates with 8; and in Canton 8 alternates with 1. It can be seen that if the three tones are coded as in Figure 1, making use of all three features, then each alternation can be described by changing the specification of one feature. In particular, the type of alterna-
tion exemplified by the Chaozhou tones provides the crucial evidence for the feature CONTOUR.

![Diagram of tone systems](image)

**Figure 1.** Fragments of tone systems

### 1.6 Phonetic Interpretation

Though subject to small variations from language to language that have no cognitive import, the range of voice pitch remains remarkably uniform across languages. This is true regardless of how many tones a language has, or whether it has any at all. In general I find it extremely difficult to distinguish utterances in certain types of tone language (e.g. Mandarin) from those in a non-tone language (e.g. English) by just examining the pitch measurements of these utterances. In languages with numerous syllable-sized tones one would expect that the utterances would have more complex pitch contours, i.e. directional changes in pitch occurring over shorter time spaces, but so far this problem has not been studied in a systematic way.\(^{27}\)

No matter how many tones a language has, the voice pitch traverses approximately the same overall range. The difference resides in how each pitch value is interpreted vis-à-vis the particular tone paradigm. The greater the number of distinct tones in the paradigm, the narrower the phonetic range of each tone would be. Furthermore, the phonetic differences among tones, in terms of pitch level, slope of contour, duration, etc., are characteristically more pronounced in deliberate speech and are reduced with increased tempo.\(^{28}\) In these respects the phonetic variation of tone is essentially similar to that of vowel articulation, since both voice pitch and vowels vary along physical dimensions which are continuous, as against certain dimensions of consonant articulations which are discrete.

It will be noted from Table I that a maximum of five level tones are posited. As observed earlier in this paper, systems which have five level tones are extremely rare, so the feature MID is rarely used. The feature HIGH specifies whether the pitch level of a
tone is above or below some idealized pitch median. The feature CENTRAL specifies whether the pitch level of a tone is close to the median. These remarks, taken in conjunction with the observations made in the preceding paragraphs, should provide a straightforward phonetic basis for interpreting the features of tone.

A phonetic interpretation of the level features is given schematically in Figure 2. The pitch median is designated 0 and the range is taken to be from −5 to +5. The effect of the feature HIGH, viewed this way, is simply to provide a sign, '+' or '−'. The feature CENTRAL restricts the range to ±3. In actual speech, of course, the phonetic boundaries are by no means as clearcut as suggested in this illustration.

There are advantages for considering the tone features to be binarily valued, as proposed here. The tone features can be regarded as having theoretical status comparable to that of the segmental features (e.g. VOICE, NASAL, STRIDENT, etc.) and can be manipulated by the same machinery of rule application that has been developed on the basis of segmental features, including the use of the 2-valued variables. An example will be provided in 1.8 that makes special use of phonological variables in solving a problem of tone sandhi, though these variables were first conceived in connection with assimilation and dissimilation of segmental features.

<table>
<thead>
<tr>
<th>Number of Pitch levels</th>
<th>Pitch Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 levels</td>
<td>0, ±1</td>
</tr>
<tr>
<td>3 levels</td>
<td>0, ±1, ±3</td>
</tr>
<tr>
<td>4 levels</td>
<td>0, ±1, ±3, ±5</td>
</tr>
<tr>
<td>5 levels</td>
<td>0, ±1, ±3, ±5, ±7</td>
</tr>
</tbody>
</table>

Figure 2. Illustration of the phonetic range of noncontour features.
LEVEL would have five possible specifications, i.e., 1, 2, 3, 4, and 5. The specifications for this feature would not be commensurate with the specifications of the other tone features and the segmental features, many of which are obviously binarily valued. The theoretical machinery of rule application cannot be easily extended to this 5-valued feature.

We face a more serious difficulty when we try to relate the specifications of LEVEL to their phonetic range in a fashion that is illustrated in Figure 2. With the features illustrated there, the principle is self-evident whereby the phonetic range of each additional tone is marked off from the middle, compressing the range at the two extremities. To achieve the same desired effect, we would be required to stipulate additionally that if a language has two NONCONTOUR tones, then they are 1 LEVEL, and 5 LEVEL (or, perhaps, 2 LEVEL and 4 LEVEL); if it has three NONCONTOUR tones, then they are 1 LEVEL, 3 LEVEL, and 5 LEVEL; and if it has four NONCONTOUR tones, then they are 1 LEVEL, 2 LEVEL, 4 LEVEL, and 5 LEVEL. This difficulty of premature commitment to phonetic detail is not unlike the problems connected with overdifferentiation discussed in 1.4.

The merit that has been argued for such a feature as LEVEL has to do with the description of a certain type of sandhi which systematically lowers or raises the pitch range of each of the NONCONTOUR tones. I cannot say at present how typical such sandhi is vis-a-vis other observed types. We have such a case, for instance, in Gaoxiong, where the high tone becomes the mid tone, the mid tone becomes the low tone, and the low tone becomes the falling tone in a given syntactic environment. Let us consider this Gaoxiong case together with a hypothetical 4-tone case which has similar pitch lowering.

Using the 5-valued feature to represent the three Gaoxiong tones as 5 LEVEL, 3 LEVEL, and 1 LEVEL, the sandhi would have to be described by a sort of rule of phonological arithmetic that subtracts 2 from each of the first two tones. It is not clear what should be done with the 4-tone case since the tones are not 'equidistant' from each other. In both cases, we need some ad hoc convention for what happens when the remainder of the subtraction is less than one.

These difficulties do not present themselves within the binary framework proposed here. To describe a 3-tone paradigm that undergoes pitch lowering, the mid tone should be specified as -HIGH and +CENTRAL. (If the paradigm undergoes pitch raising, the mid tone should be +HIGH and +CENTRAL; cf. the discussion on alternative phonological representations in 1.5 above.) The appropriate sandhi rule would be:

\[
[e\text{HIGH}] \rightarrow \begin{bmatrix} -\text{HIGH} \\ -\alpha\text{CENTRAL} \end{bmatrix}
\]

For the 4-tone paradigm that undergoes pitch lowering, the following rule must be supplemented by a later rule that corrects the derivation of the lowest tone:
The strongest evidence in support of the binary features comes from alternations that may be called 'flip-flops'. These are cases where, in certain linguistic environments, the high tones become low tones and the low tones become high tones. Such alternations have been reported for many Chinese dialects, as well as for other languages. In some cases these alternations are synchronic; in others, they are deducible only historically by comparing cognates. We have a synchronic example in the dialect of Chaozhou, where it is reported that before a high falling tone, (i) high tone becomes low tone, (ii) low tone becomes high tone, and (iii) mid tone remains unchanged. These flip-flop alternations which involve just the two extremities of the pitch range cannot be as easily stated within an n-ary framework. Using the features of the present theory, however, they have a natural expression as follows:

\[ \begin{bmatrix} \alpha \text{HIGH} \\ \beta \text{CENTRAL} \end{bmatrix} \rightarrow \begin{bmatrix} -\beta \text{HIGH} \\ \alpha \text{CENTRAL} \end{bmatrix} \]

According to Egerod, such a situation as that of Chaozhou is quite wide-spread in the southern Chinese dialects. He remarks that in Middle Chinese tone 3 in the Min dialects, and in Middle Chinese tone 4 in the Min and Hakka dialects, "the words which have developed from forms with voiced initials are higher pitched than those derived from forms with unvoiced initials." From the physiological considerations alluded to in 1.2, we know that these dialects must have undergone a flip-flop historical change of the sort exemplified in the above rule. Further-more, this change has left a synchronic imprint in many Min dialects where words which had voiced initial consonants have sandhi forms that are lower pitched than the corresponding words which had unvoiced initial consonants.

Such alternations pose a striking problem for our understanding of phonological change. Assuming that there are no other relevant factors, it is difficult to see how a historical flip-flop such as one between high tone and low tone can be brought about without the two tones merging with each other at some stage of change, if one views this type of change as occurring in small cumulative phonetic increments. The possibility is always open, of course, for one of the tones to become something else during an intermediate stage to avoid the collision course. However, the force of this explanation is diminished when we see that in many cases (i) the tones involved are phonetically short at both the initial and terminal stages of the change, making the distinctive use of CONTOUR features unlikely, and (ii) the present morphophonemic alternation is between +HIGH and −HIGH NONCONTOUR tones, making the hypothesis of an intermediate stage
unlikely. One could interpret the flip-flop as occurring in an all-or-none fashion over a gradually increasing sector of the vocabulary and thereby avoid the conceptual difficulties of the dilemma of inevitable collision. Even in this view, however, interesting questions arise in connection with the effect this change has on intelligibility.

1.7 Marking Conventions

Although the redundancy conventions allow us to deduce which feature combinations are permitted by the theory, they do not indicate which ones are favored. Languages with three tones would characteristically have tones 1, 2, and 5 of Table 1, or perhaps 6, 8, and 5; we would hardly expect them to have, say, tones 1, 3, and 6 or 1, 10, and 11. Languages with four tones may have tones 1, 2, 6, and 8 or 1, 2, 8, and 13; but hardly ever 1, 2, 3, and 4, or 6, 7, 8, and 9. The situation is not unlike that of segmental features where we find that (a) certain features are exploited more than others, i.e. HIGH more than CONTOUR which in turn is more exploited than CONVEX (cf. VOCALIC more than STRIDENT, while STRIDENT is more exploited than GLOTTALIZED); and (b) more dimensions are utilized rather than more distinctions within a single dimension. This latter point explains why a four-tone paradigm always has some CONTOUR tones, even though many languages do distinguish among four NONCONTOUR tones. CONVEX tones are only found in rather complex paradigms containing at least five or six tones. As mentioned above, only very rarely is the feature MID exploited to distinguish five CONTOUR tones, though paradigms containing more than five tones are not uncommon.

Table 2. Relative Complexity of Tones as Defined by Marking Conventions

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONTOUR</td>
<td>u</td>
<td>u</td>
<td>u</td>
<td>u</td>
<td>u</td>
<td>m</td>
<td>m</td>
<td>m</td>
<td>m</td>
<td>m</td>
<td>m</td>
<td>m</td>
<td></td>
</tr>
<tr>
<td>HIGH</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>CENTRAL</td>
<td>u</td>
<td>u</td>
<td>m</td>
<td>m</td>
<td>m</td>
<td>u</td>
<td>u</td>
<td>u</td>
<td>u</td>
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<td>u</td>
<td>u</td>
<td></td>
</tr>
<tr>
<td>MID</td>
<td>u</td>
<td>u</td>
<td>u</td>
<td>u</td>
<td>m</td>
<td>u</td>
<td>u</td>
<td>u</td>
<td>u</td>
<td>u</td>
<td>u</td>
<td>u</td>
<td></td>
</tr>
<tr>
<td>RISING</td>
<td>u</td>
<td>u</td>
<td>u</td>
<td>u</td>
<td>u</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>FALLING</td>
<td>u</td>
<td>u</td>
<td>u</td>
<td>u</td>
<td>u</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>CONVEX</td>
<td>u</td>
<td>u</td>
<td>u</td>
<td>u</td>
<td>u</td>
<td>u</td>
<td>u</td>
<td>u</td>
<td>u</td>
<td>u</td>
<td>m</td>
<td>m</td>
<td></td>
</tr>
<tr>
<td>COMPLEXITY</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

Table 3. Tones of Amoy Hokkien

<table>
<thead>
<tr>
<th>Ig</th>
<th>lb</th>
<th>II</th>
<th>IIIa</th>
<th>IIIb</th>
<th>IVa</th>
<th>IVb</th>
</tr>
</thead>
<tbody>
<tr>
<td>HIGH</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>FALLING</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>RISING</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>LONG</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
A preliminary attempt at formalizing these preferences for combinations of feature specifications is made in Table 2. It will be seen that the 'u' specification (unmarked) always happens to correspond to the '−' specification of Table 1, and that the 'm' specification (marked) always happens to correspond to the '⁺' specification. The 'u' specification, which is the favored specification, does not add to the complexity of a sound system, whereas the specifications '⁺', '−', and 'm' each add one unit to the complexity.

To convert the 'u' and 'm' to '⁺' and '−' all that is needed is the following general marking convention which turns 'u' to '−' while its implied inverse convention turns 'm' to '⁺'.

\[ [u \text{ TONE FEATURE}] \rightarrow [-\text{ TONE FEATURE}] \]

The assignment of '⁺' and '−' in Table 2 is straightforward, since there is no empirical ground for favoring either [+HIGH] or −HIGH, or RISING or FALLING. The preference for −CONTOUR is justified by the preponderance of languages with only −CONTOUR tones. Among the bidirectional tones there seems to be a majority of −CONVEX tones in the literature I surveyed. The bidirectional tones almost always become unidirectional tones in sandhi; very rarely does any tone become a bidirectional tone in sandhi. When a bidirectional tone like tone 10 changes, it usually becomes either tone 6 or tone 8; i.e. tone 10 loses either its first half or its second half. In such cases one of the following two symmetric conventions will apply.

1. \[ [+\text{ RISING}] \rightarrow [u \text{ RISING}] / [+\text{ FALLING}] \]
2. \[ [+\text{ FALLING}] \rightarrow [u \text{ FALLING}] / [+\text{ RISING}] \]

The content of Table 2 and the associated marking conventions must be regarded as highly tentative at this time. To provide an adequate empirical basis for such statements, much more extensive results on diverse forms of tone alternations are required than are now available. Furthermore there are great gaps in our present understanding of the theoretical basis of marking conventions that need to be filled. However, the exercise in this section does indicate that in this area of phonological research tone features can be treated in essentially the same way as the segmental features.
1.8 Tone Circle in Min

The use of the tone features presented here may be exemplified by a particularly interesting phenomenon of sandhi in Amoy Hokkien.\textsuperscript{35} In Table 3 we present the seven lexical tones of this Chinese dialect in terms of the values they have when pronounced as citation monosyllables. The numbers we assign to the tones correspond etymologically to the four tones of Middle Chinese, believed to have been spoken some 1,500 years ago. The letters 'a' and 'b' indicate a historical split that corresponds respectively to unvoiced and voiced initial consonants. In most of the Min dialects, of which Amoy Hokkien is one, Middle Chinese tone 2 did not participate in the split.

In a large class of syntactic environments,\textsuperscript{37} the tones undergo sandhi in a way that is illustrated by Bodman's examples below. In the discussion here we will be concerned with the five long tones only.

A closer inspection of these alternations will show that there is some underlying regularity that may be extracted. Indeed Bodman presents these alternations in the form of a tone circle which can be linearized in the formula:

\[
\begin{align*}
1a & \rightarrow 1lb \rightarrow 1la \rightarrow 11 \rightarrow 1a \\
1b &
\end{align*}
\]

The neutralization of tones 1a and 1b in the sandhi position enables us to restate the above formula in terms of only two phonological features. It is understood, of course, that these features are in the environment \textit{LONG}, as discussed above.

\[
\begin{align*}
+\text{HIGH} & \rightarrow [+\text{HIGH}] \\
-\text{FALLING} & \rightarrow [-\text{FALLING}] \\
-\text{HIGH} & \rightarrow [-\text{HIGH}] \\
+\text{FALLING} & \rightarrow [+\text{FALLING}] \\
-\text{FALLING} & \rightarrow [-\text{FALLING}] \\
+\text{HIGH} & \rightarrow [+\text{HIGH}] \\
-\text{FALLING} & \rightarrow [-\text{FALLING}] \\
\end{align*}
\]

The regularity in these alternations can be clearly seen from the above formulation. In each alternation only one feature changes its specification. Furthermore we can predict which feature will change its specification. If the two features of the basic tone have the same specification, then \textit{FALLING} will change its specification. Otherwise, \textit{HIGH} will change. These observations lead us to discover that the \textit{HIGH} feature of the derived tone takes on the same specification as the \textit{FALLING} feature of the basic tone, while the \textit{FALLING} feature of the derived tone takes on the opposite specification of the \textit{HIGH} feature of the basic tone. In sum, all four pair-wise alternations can be captured by the single phonological rule:
Notes

1. The most comprehensive investigation of tone languages to date continues to be K. L. Pike's book of 1948, though new data have led to criticisms of some of Pike's assumptions; e.g. W. E. Welmers, Tonemics, morphonemics, and tonal morphemes, General Linguistics 4:1-9 (Spring, 1949). A lucid discussion on the range of the term 'tone language' by James D. McCawley in a paper entitled 'What is a tone language?' was presented to the Linguistic Society of America, August, 1964, in which he correctly pointed out that attempts at typology of this sort should be based primarily on the abstract form of phonological rules which the different tonal structures require. He argued convincingly that languages with the so-called pitch accent, e.g. Japanese, though frequently grouped with tone languages, are much more similar phonologically to certain non-tone languages. Indeed, it is an open question whether the distinction between these two types of accent can be given any phonetic foundation. Although this distinction has played a prominent role at least since Karl Verner used it as part of his famous historical thesis, our understanding of the physical basis of this distinction has not advanced much, in the past century.


5. See, for example, Robert E. Longacre, Trique tone morphemics, A L (Anthropological Linguistics) 1:45-42 (April, 1955); A. Meeussen, Syntactic tones of nouns in Ganda: a preliminary synthesis, Linguistic Research in Belgium 77-86, Universa Watteren, Belgium (1966).


8. For a clearly presented example of a terrace-level tone language in Ghana, see Paul Schachter, Phonetic similarity in tonemic analysis, Lg 37:231-8 (1961). In the same issue of Language, H. A. Gleason, Jr. gives additional discussion of this tonal phenomenon within the broader framework of Niger-Congo languages, Lg 37:294-303, 1961. These African languages are terrace-level languages of the descending variety in that the pitch of the voice characteristically progresses from high to low. Eunice Pike recently called my attention to a terrace-level language of the ascending variety, i.e., the Acatan dialect of Mixtec, where the voice pitch may be raised an indefinite number of steps theoretically, by the repeated occurrence of the tone feature 'step-up'. I am grateful to Miss Pike for showing me an unpublished paper on this subject, which she co-authored with Kent Wistrum. The tone features 'step-up' and 'step-down' are not discussed in the present study since they fall into play a type of phonological formalism that remains to be developed should they prove necessary at a systematic phonemic level of representation.


13. The notion of 'marked' and 'unmarked' has been used by N. S. Trubetzkoy in connection with what he called 'private oppositions', i.e. oppositions which are characterized by the presence or absence of certain features such as voicing, nasality, rounding. In his Principe de Phonologie, the notion was mentioned briefly but not developed. Recently Halle and Chomsky integrated this notion into their framework of generative phonology in an attempt to capture the asymmetric nature of phonological features; see their Sound Pattern of English, now in press with Harper and Row. For reasons which have mostly to do with the physical constraints on the speech mechanism, the two specifications of a phonological feature frequently are not symmetric with each other. Furthermore, such asymmetry may be context-sensitive, e.g. the dependence of voicing on consonantality, or it may be context-free, e.g. sounds are generally unglottalized. This observation is equivalent to the one I am making regarding certain combinations of feature specifications being favored over others.
14. For a discussion of a phonological entity that has been particularly elusive to phonetic investigation, see my Stress in English, Language Learning 12.69-77 (1962).
15. An attempt has been made to categorize the various linguistic functions of voice pitch in the reference given in footnote 10. A pioneering paper in this area is Y. R. Chao's Tone and intonation in Chinese, Bulletin of the Institute of History and Philology (Academia Sinica) 4.121-34 (1933).
17. Some Tai languages of Guizhou are also reported to have five level tones; cf. Report of the Survey of Buyi Languages, Peking, 1959 (in Chinese). I have not studied whether any of these levels can be predicted by other features which are independently distinctive, such as syllable length or consonantal voicing.
19. The data here were gathered by F. K. Li some years ago and reported by Julia Kwan in a University of Washington M.A. thesis (1966), Phonology of a Black Miao Dialect.
20. In Longacre's analysis a phonemic fifth level is posited but no contour tones are used; the reference is given in fn. 7.
25. See reference in Footnote 3.
27. In some languages with only noncontour tones, especially those of the terrace-level type, the pitch contours assume a remarkable stepfunction appearance.
28. For a more detailed discussion of these matters, see K. L. Pike, Operational phonemics in relation to linguistic relativity, Journal of the Acoustical Society of America 24.618-24 (1952). Pike pictures the relation between the global contour and the local contours as that of a large cable containing smaller cables. Other suggestive metaphors include that of ripples superimposed on a wave, and that of contours drawn on a rubber sheet which may be stretched in various ways.
29. Peter Ladefoged has expressed the view that the features should not be binarily-valued in a paper entitled An attack on the number two, presented to the Acoustical Society of America, June 1960; see UCLA Work Papers in Phonetics No. 4 (July 1968), 7-9. I believe his arguments against binary tone features are met in the present paper.
30. To my knowledge, variables were first introduced by Morris Halle in his A descriptive convention for treating assimilation and dissimilation, Quarterly Progress Report No. 86 of the M.I.T. Research Laboratory of Electronics (1962), 295-6.
31. Chao-Hui Tung, Phonology of Taiwanese as spoken in the Kaohsiung area, *Journal of Taiwan Provincial Normal University* 9.1-10 (June, 1964).

32. Reference given in Footnote 26. William Merrifield recently called my attention to the existence of a synchronic flip-flop in Palantia Chintanc. On p. 9 of his *Korean Morphophonemics*, Baltimore, 1954, Samuel Martin describes a situation that seems to be a diachronic flip-flop, which is not unlike what happened to the lexical accent in Japanese dialects, as he pointed out. Of related interest is the observation that some British dialects of English have reversed pitch contours; see Barbara Strang's remark on p. 845 of *Proceedings of 8th International Congress of Linguists*.


34. A comprehensive discussion of the theoretical issues involved in phonological change is given by Paul M. Postal in his *Aspects of Phonological Theory*, in press with Harper and Row. The problem of flip-flop changes has been discussed in detail by Robert P. Stockwell in a paper read to the Linguistic Society of America called Realism in historical English phonology (December 1964) and in some later unpublished papers. For an early statement to the effect that phonetic changes are always by abrupt leaps rather than successive slides, see Alf Sommerfelt, *Note sur les changements phonétiques*, *Bulletin de Société de Linguistique* 24:138-41, 1923.

35. One case that has come to my attention recently is Zheng, Tone sandhi in the Wenzhou dialect (in Chinese), *Zhongguo Yuwen* 129:106-52 (1964).


37. A detailed study of the syntactic environments in which similar sandhi takes place in a Taiwanese variety of Min is available in a forthcoming paper by Robert L.W. Cheng. Roughly speaking, the sandhi occurs on all syllables which do not end major syntactic phrases. It seems to be general with Chinese dialects that sandhi is conditioned by syntactic boundaries on the one hand and speech tempo on the other. For examples and discussion on this point see Cheng, Mandarin phonological structure, *Journal of Linguistics* 2:135-58 (1966), especially pp. 159-1; and my Tone 3 in Pekinese, to appear in *Journal of Speech and Hearing Research* (1967).