The Sonority Hierarchy

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0. In what we will refer to as "standard" phonological theory, essentially that developed in Chomsky and Halle (1968) and widely accepted as a basic framework for phonological description, it is assumed that phonological rules distinguish segments on the basis of binary-valued distinctive features, and that only classes readily characterizable in terms of combinations of such features should be referred to by rules in the phonology of natural languages. This theory makes the claim that the only relations among classes which phonological rules need to refer to are cross-classifying taxonomic ones; it claims in particular that no phonological process will ever depend on hierarchical relations among phonological classes. In this paper we will show that there is an assimilation rule in Pali (a classical language of India) which can be adequately stated only in terms of just such a hierarchical relation among classes.

We will propose that the required hierarchical relation, which we will call sonority, must be directly represented in some fashion so that phonological rules can refer to it. We will propose a formalism for this purpose, and show that the incorporation of this device into phonological theory leads to a fundamental revision of the distinctive feature system.

1. The Pali Assimilation Rule

1.1. In Pali, a middle Indic dialect, the following regularities are found:

(a) both morpheme-internally and across morpheme boundaries, the only consonant clusters are the following:

\[\text{Nasal + homorganic stop} \]
\[\text{stop + homorganic aspirate} \]
\[\text{geminate consonants} \]

(The stop + homorganic aspirate clusters can be viewed as aspirated geminates, with aspiration realized only at the offset of the cluster, so that the only legitimate clusters are homorganic nasal-stop clusters and geminates.)

(b) when two nonidentical consonants come together at morpheme boundary, either

(i) the cluster is broken up by the insertion of an apophonic vowel, or

(ii) one of the two consonants assimilates to the other. In the case of nasal-stop clusters, the nasal assimilates in place of articulation to the stop; in other cases the assimilation is complete; the assimilating consonant assimilates in all features to the other.
These processes of assimilation and epenthetic vowel insertion were a feature of many middle Indic dialects. They are the result of phonological change, and the original state of affairs, where non-geminate clusters were allowed, is reflected in Sanskrit. We are concerned here with the rule of consonant assimilation and will henceforth ignore epenthetic vowel insertion.

There are various complications superimposed on the generalization stated above which result from the interaction of the consonant assimilation rule with other rules. We will mention these as they arise, but as they are for the most part irrelevant to the main point, we will not discuss them in detail.

The direction of assimilation depends on the nature of the consonants involved. Given the hierarchy

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stops < nasals < y < r
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the rule can be stated as follows:

(a) the consonant lower on the hierarchy (toward r) assimilates in all features to the consonant higher on the hierarchy (toward stops);
(b) if the consonants are of equal rank on the hierarchy, the assimilation is regressive (the first assimilates to the second).

1.2. In this section, we give evidence for the hierarchical nature of the CA process. We will distinguish between evidence which shows that there was a hierarchically operating synchronic rule of CA in Pali and evidence for a hierarchically governed diachronic assimilation. In general, because of the limited number of suffixes involved in the alternations, various leveling processes, and the interference of epenthetic vowel insertion, the evidence for the latter is more complete than for the former. Sufficient evidence remains, however, to demonstrate that a hierarchical assimilation rule was synchronically operative in Pali.

Most of our examples will be taken from the verbal system, since almost all nouns in Pali are thematic, i.e., the stem ends in a vowel. Root-final consonants stand adjacent to suffix-initial consonants in the following forms: past participle -ta/-na; infinitive -tum; passive -ya; future -ssa; gerund -ya; gerundive -tabba; a-solit -g. Limited space precludes full citation of examples; the examples we give should be taken as representative of large classes of regular alternations.

1.2.1. a always assimilates to a neighboring stop:

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vas + tum → vatthum
vak + ssa- → vakkuha-
```

(int. vas 'to dwell'

(fut. vak 'to speak'

(note: a causes aspiration of a neighboring stop; there must also be low-level rules reducing all clusters of more than two identical consonants to geminates, and transporting aspiration to the offset of the cluster.)

1.2.2. y assimilates:

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dis + yi
kas + y
```

1.2.3. If the CA rule y assimilates to a stop, and it does:

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pec + yr
arah + y
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1.2.4. Consider now:

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kar + yr
udir + y
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1.2.5. From this we and it does:

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kara + as
Skt. mif
kar + t
```

1.2.6. The position of nasals assimilate to:

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lag + na
khan + y
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(y causes palatalization)

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gam + ya
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These facts show the and the oral stops do in Pali as to the re cause a preceding a does not participate a nasal causes the n vowel. Evidence for however, indicates ti For example, corresp o synchronically retain

Pali ra:

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1.2.7. There is hist hierarchy, r assimil

Skt. kal, kaly
1.2.2. \( \gamma \) assimilates to a neighboring \( \delta \):

\[
\begin{align*}
\text{dis} + \text{ya-} & \rightarrow \text{dissa-} & \text{pass. dis 'to see'} \\
\text{kas} + \text{ya-} & \rightarrow \text{kassa-} & \text{pass. kas 'to farm'}
\end{align*}
\]

1.2.3. If the CA rule operates in hierarchical fashion, then since \( \gamma \) assimilates to \( \delta \) and \( \delta \) to stops, we predict that \( \gamma \) assimilates to stops, and it does:

\[
\begin{align*}
\text{pac} + \text{ya-} & \rightarrow \text{pacca-} & \text{pass. pac 'to cook'} \\
\text{arabh} + \text{ya} & \rightarrow \text{arabhna} & \text{gerund arabh 'to begin'}
\end{align*}
\]

1.2.4. Consider now the fact that \( \delta \) assimilates to \( \gamma \):

\[
\begin{align*}
\text{kar} + \text{ya-} & \rightarrow \text{kayya-} & \text{pass. kar 'to make'} \\
\text{udir} + \text{ya} & \rightarrow \text{udliya-} & \text{pass. udir 'to utter'}
\end{align*}
\]

1.2.5. From this we predict that \( \gamma \) assimilates to \( \delta \) and to stops, and it does:

\[
\begin{align*}
\text{kar} + \text{sa-} & \rightarrow \text{kassa-} & \text{fut. kar 'to make'} \\
\text{Skt. mīra} & \sim \text{Pali nissā 'mixed' [historical evidence]} \\
\text{kar} + \text{tun} & \rightarrow \text{kattun} & \text{inf. kar 'to make'}
\end{align*}
\]

1.2.6. The position of nasals is established by observing that nasals assimilate to stops and \( \gamma \) to nasals:

\[
\begin{align*}
\text{lag} + \text{na} & \rightarrow \text{lagga} & \text{P. lag 'attach'} \\
\text{khan} + \text{ya} & \rightarrow \text{khanā-} & \text{pass. khan 'to dig up'}
\end{align*}
\]

(\( \gamma \) causes palatalization of a preceding stop prior to CA.)

\[
\begin{align*}
\text{gam} + \text{ya} & \rightarrow \text{gama} & \text{gerundive gam 'to go'}
\end{align*}
\]

These facts show that nasals, like \( \delta \), occupy a position between \( \gamma \) and the oral stops on the hierarchy. There is a paucity of evidence in Pali as to the relative position of nasals and \( \delta \). This is because \( \delta \) preceding a nasal usually turns into \( \delta \) prior to CA, and \( \delta \) does not participate in the assimilation process; and \( \gamma \) following a nasal causes the nasal to disappear, nasalizing the preceding vowel. Evidence from other Prakrits which also had the CA rule, however, indicates that \( \delta \) is higher on the hierarchy than nasals. For example, corresponding to a Pali form in which \( -\text{sa} \) was idiosyncratically retained, other Prakrits have \(-\text{ss} \):

\[
\begin{align*}
\text{Pali rasmi} & \sim \text{Prk. rassi 'rope'}
\end{align*}
\]

It seems to have been on the basis of facts like these that Geiger ordered \( \delta \) above the nasals on the dominance hierarchy. If there is better synchronic evidence for the \( \delta \) > nasals dominance, we have been unable to find it.

1.2.7. There is historical evidence for two more positions on the hierarchy. \( \lambda \) assimilates to nasals and \( \gamma \) assimilates to \( \lambda \), placing \( \lambda \) between \( \gamma \) and the nasals on the hierarchy:

\[
\begin{align*}
\text{Skt. kalmāsa} & \sim \text{Pali. kammāsa 'freckled'} \\
\text{kalya} & \sim \text{kella 'ready'}
\end{align*}
\]

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stop:

\text{vas} 'to dwell' 
\text{vak} 'to speak' 

\( \gamma \) has more than two identi-
state to the
From this we correctly predict that \( l \) will assimilate to stops:

\[
\text{kibbi}a \sim \text{kibbi}a \quad \text{'guilty'}
\]

We also predict that \( l \) will assimilate to a neighboring \( s \). Evidence is lacking.

1.2.8. There is historical evidence that \( y \) (which was probably a glide, i.e. \( w \)) stands between \( l \) and \( y \) on the hierarchy. \( y \) assimilates to \( l \), \( y \) assimilates to \( y \):

\[
\text{Skt. bilva} \sim \text{Pali billa} \quad \text{'a fruit'}
\text{khalv}a \sim \text{khal}a \quad \text{'hale'}
\text{pariyaya} \sim \text{paribbaya} \quad \text{'reward'}
\text{havva} \sim \text{hahba} \quad \text{'in condition to'}
\]

[Note: In Pali \( vv \to \text{bb} \) subsequent to CA.]

From this we predict correctly that \( y \) will assimilate to a neighboring stop, \( s \), or nasal:

\[
\text{prajvalati} \sim \text{pajjalati} \quad \text{'it burns'}
\text{cettvras} \sim \text{cattaro} \quad \text{'four'}
\text{afva} \sim \text{assa} \quad \text{'horse'}
\text{kinva} \sim \text{kina} \quad \text{'yeast (?)'}
\]

Further, we correctly predict that \( r \) assimilates to \( y \):

\[
\text{sarva} \sim \text{sabba} \quad \text{'all'}
\text{kuvranti} \sim \text{kubba} \quad \text{'they make'}
\]

1.2.9. We have now established the following relations:

[Diagram showing relationships among stops, \( s \), and \( \gamma \).]

Diachronically

1.3. In this section we present, briefly, evidence that when two unlike adjacent consonants are of the same rank on the hierarchy, the first assimilates to the second,

\[
\begin{align*}
\text{Sup} + \text{ta} & \rightarrow \text{sutte} & \text{P.P. sup} & \text{'to sleep'} \\
\text{Dhnn} + \text{ta} & \rightarrow \text{bhutte} & \text{P.P. dhnn} & \text{'to eat'} \\
\text{sam} + \text{nisid} & \rightarrow \text{sannisid} & \text{ind. sam-nisid} & \text{'to be quiet'} \\
\text{Skt. nimase} & \sim \text{Pali nina} & \text{'low-lying'} \\
\text{umulanayati} & \sim \text{umuleti} & \text{'uproot'}
\end{align*}
\]

1.4. There are two systematically failed above, clust complete assimilations, furthermore, in the ca-

[Note: In Pali \( vv \to \text{bb} \) subsequent to CA.]

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We have established of the relations when a consonant \( x \) assimilates cannot be represented exclusively on basis:

[Diagram showing relationships among stops, \( s \), and \( \gamma \).]

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[Diagram showing relationships among stops, \( s \), and \( \gamma \).]

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2.1. It is clear the action rule requires a change hierarchy, with a scale of "morality"
1.4. There are two classes of unlike consonant clusters which systematically fail to assimilate in the general manner. As mentioned above, clusters of nasal + homorganic stop do not undergo complete assimilation, although clusters of stop + nasal do. Furthermore, in the case of voiced stops + homorganic nasals, i.e. -dn- and -jñ-, the assimilation is to -m- and -ñm- rather than to -dd- and -jj-.

\[
\begin{align*}
nud + nā & \rightarrow munna \\
rāj + nā & \rightarrow ranna \\
p.p. nūd 'to remove' & \rightarrow mun \\
inst. sg. rājā 'king' & \rightarrow ranna
\end{align*}
\]

This misdirected assimilation is the result of a historically prior change (attested as early as Vedic Sanskrit); we will assume that synchronically it is to be accounted for by a special rule for these clusters preceding the general CA rule.

2.0. Statement of the CA rule
We have established in the last section the hierarchical nature of the relations which determine the direction of assimilation. If a consonant \( x \) assimilates to a consonant \( y \), and \( y \) assimilates to \( z \), then \( x \) also assimilates to \( z \). This is a kind of relation which cannot be represented directly in terms of representations based exclusively on binary distinctive features. Since there is no way in such a system to represent hierarchical relations, it will be impossible to distinguish the naturalness of the Pali CA rule from one like it in all respects except that, for example, \( y \) assimilates to \( r \) and not vice versa.

There are various ways that the CA rule could be formulated in terms of binary features. There is no way, however, that does not involve dividing the rule up into several unrelated rules, e.g. one which assimilates non-obstruents to adjacent obstruents, one which assimilates continuants to adjacent noncontinuants, etc. A number of specific rules would be required to account for assimilations involving liquids and glides, and the hierarchical nature of the process would go unexpressed. Such a formulation would claim, in effect, that the hierarchical relations established in the last section are not systematic but accidental.

We must conclude that a theory which only allows rules formulated in terms of binary distinctive features is inadequate, in that it cannot in principle capture the generalization inherent in the hierarchical behavior of consonants in the Pali assimilation rule. In this section we propose a formalism for stating such a rule, and show that the incorporation of the required device into phonological theory has drastic consequences for the distinctive feature system.

2.1. It is clear that the proper formulation of the Pali assimilation rule requires minimally a statement of the consonantal dominance hierarchy, which we represent here, following tradition, as a scale of "sonority":

\[
\begin{align*}
\text{stops} & \rightarrow \text{nasals} & \text{\( l \)} & \text{\( v \)} & \text{\( y \)} & \text{\( x \)} \\
& & \text{greater sonority}
\end{align*}
\]
In order to incorporate this scale into a theory which takes, for example, the Chomsky-Halle binary distinctive features as basic, it is necessary to represent each of the classes (or "steps") along the ladder in the binary features provided by the theory, or to formulate slightly more general statements establishing the relationship of classes defined by the binary features along the hierarchy. Secondly, some kind of variable notation must be introduced to allow reference to relative positions on the hierarchy:

\[ C_x \to C_y \text{ or } C_x > C_y \text{ on the sonority hierarchy} \]

(Here we make use of the mirror image notation together with the convention that the first expansion is in the order indicated by the environment bar, so that when \( C_x \) and \( C_y \) are equal in sonority, the assimilation will be regressive, as required. \( C_x \) and \( C_y \) are, of course, cover terms for more complex representations in the binary feature notation.)

It seems that something along these lines would be the minimal required addition to the standard framework, if the Pali assimilation rule is to be formulable.

2.2. A More Radical Proposal

We will suggest, however, that this minimal adjustment is the wrong one. It would treat the hierarchical relation of sonority as a derivative notion, defined in terms of the "standard" binary distinctive features, and having no independent phonological reality. What we propose is that the feature of relative sonority is phonologically primitive and not to be defined in terms of classifieratory features; on the contrary, we claim that once the necessity for the sonority hierarchy is recognized, and an adequate formalization of it incorporated into phonological theory, the major class features are seen to be superfluous, and rules which have been stated in terms of those features are more adequately stated in terms of the sonority hierarchy.

Note first that the statement of the hierarchy in terms of classes themselves defined in terms of classifieratory features, along the lines proposed by Zwickl (see fn. 7), simply translates the complexity of the CA rule into the complexity of the representation of the hierarchy. We will demonstrate below that this complexity cannot be filed away once and for all in universal phonological theory, for the ranking of segments along the sonority hierarchy is not fully universal; and as long as the classifieratory distinctive features are considered to be universally defined, language-particular statements concerning the correlation of these features with the sonority scale will be required.

We have shown that the sonority hierarchy is required for the adequate formulation of one rule; we will cite below examples of other rules which also require it. References already cited give evidence that such a hierarchy figures in the statement of regularities of syllable structure, phonological change, and fast speech phenomena. If the binary distinctive features of the standard theory are the appropi-
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dard theory are the appropriate device for the representation of
natural classes and the formulation of natural rules, why should
the representation of the sonority hierarchy in terms of those
features be so complex and opaque? The only conclusion, we be-
lieve, is that the sonority scale must be defined indepdendently
of the classificatory features.

We propose the introduction of a new kind of "feature" -
sonority, which may take a range of values, say from 1-9 (with
stops near the 1 end of the scale and vowels at the high end).
These numbers are arbitrary, and might as well be 0-10, -16 to
128, or anything else. Particular segments or classes of segments
are assigned to ranks along this scale, i.e. they have as one of
their "features" an index of rank on the sonority hierarchy. The
ranking for Pali is as follows:

\[
\begin{align*}
\text{stops} & : s \\
\text{nasals} & : l, v, r \\
\text{vowels} & : 1, 2, 3, 4, 5, 6, 7, 9
\end{align*}
\]

We do not know whether it is possible to provide a definition for
this feature in acoustic or articular terms. Articulatorily,
the most likely feature seems to be relative constriction at the
point of articulation (and it is generally in such terms that son-
ority has traditionally been characterized); the position of nasals
does not follow straightforwardly from this, however, and affricates
(which we assume fall between stops and fricatives) present a problem,
as does s. Attempts have been made (for example by Paul Meronel-
stein at Haskins Laboratories) to discover an acoustic indicator of
sonority, but we are unfamiliar with this work. Consequently, we will
not attempt to suggest a phonetically based definition.

Our position is that the facts force us to recognize the sono-
rity hierarchy as a phonological reality. This being the case,
our inability to define a single phonetic parameter which varies
along the hierarchy cannot prevent us from according it some status
in phonological theory. We do not see why it should be particularly
disturbing even if it should turn out that there is no such pa-
rameter -- this would simply mean that the part of the brain
which is responsible for processing speech sounds constructs "psychologi-
cal" parameters which bear no simple or direct relation to observa-
able phonetic parameters. (which is not to say that they bear no
relation to such observables -- only that the relation is complex),
which can hardly be surprising in view of what we must assume about
the complexity of speech processing anyway.

It should be noted that this sonority ranking is the one we
have found to be operative in Pali. We do not claim this parti-
cular arrangement of elements along the hierarchy to be universal;
in particular, given the relatively great ranges of possible vari-
ation in the articulation of things that we would represent as
"r" and "l", we would expect that the ordering of these elements
along the hierarchy might be quite variable, so that another dia-
lect with a more constricted r might have an ordering where r
and l are adjacent. We claim that it is precisely the variability
of glides and liquids along the sonority scale (as opposed, for example, to the stops, or the nasals, which are relatively invariant with respect to each other in sonority) which results in each liquid/glide being assigned its own rank, which shows up in the assimilation behavior.

As a result of this variability, we expect that every language has its own sonority hierarchy, or rather that the scale is universal but every language places its segment types along the hierarchy at points determined by the language-particular features of articulation: for such classes as stops, fricatives, and nasals, there is little variation from language to language, and no inversions of order. Among the liquids and glides, however, there may be considerable variation from language to language. For example, there are instances in the middle Indic dialects of assimilations in which $y + r$, instead of the expected $y$; this could be because $r$ is adjacent to $y$ on the sonority scale, and therefore can easily vary so as to occupy the same rank as $y$. This sort of reversal is expectable given the hierarchy; on the other hand, we would not expect a reversal of the relation between $r$ and $s$, or even between $r$ and $l$, unless there were also concomitant reversals between one of those and the intervening $y$ and $v$. Predictions of this sort are of course totally impossible within the binary-feature framework.

Another example of such variability is provided by a CA rule in Hungarian. We do not have the space here to document this rule with the thoroughness which has been devoted to the Pali rule, but the phenomenon is essentially the same. We can establish the following hierarchical relations:

\[
\text{stops} \rightarrow \text{fricatives} \rightarrow \text{nasals} \rightarrow \text{glides}
\]

I.e., $l$ assimilates to $r$ and $y$, $y$ assimilates to nasals, fricatives, and stops, etc. The Hungarian rule is not so pervasive as the Pali rule, in that many clusters fail to geminate; but there are no assimilations contrary to the hierarchy.

Notice that in Hungarian, if we assume that this assimilation rule is also governed by rank along the sonority scale, $l$ is more monosynomic than both $r$ and $y$. We cannot describe here the precise phonetics of these segments in Hungarian, beyond noting that $l$ is a trill, and hence, as $r$'s go, quite consonantal. There is, however, independent phonological evidence to support this ranking.

Note that, under the assumption that in general syllable-final clusters will exhibit monotonically decreasing sonority, the occurrence of $y + r$ or $l + r$ final clusters in Hungarian would counter-exemplify the postulated ranking. No such clusters occur, however. The only permissible final clusters are nasal, $y$, $l$, or $l +$ stop; and there is evidence that the $y +$ stop clusters are less preferred than the $r$, $l$, $+$ stop clusters.

There is a rule of vowel epanthesis which operates in noun paradigms as follows: if a suffix consisting of a single stop
as opposed, for relatively invariable results in each illows up in the ass-
that every language the scale is universal along the hierarch-
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However, there may be.
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\[
[\text{+ cons}] \rightarrow [\alpha \forall] \quad \% \quad [\text{- voc}] \quad [\text{m son}] \rightarrow [\alpha \forall] \quad [\text{+ cons}] \quad [\text{m son}] \rightarrow [\alpha \forall] \\
\text{where } m \geq n 
\]

Here we introduce a notation to allow quantification over all features of a segment -- a device which is necessary in any case for complete assimilation phenomena.

but now notice that our sonority hierarchy itself provides a way of characterizing the class of segments which undergo the rule: it's exactly the segments with a sonority value less than or equal to that of \( \alpha \). So we can write the rule

\[
[\text{n son}] \rightarrow [\alpha \forall] \quad \% \quad [\text{m son}] \rightarrow [\alpha \forall] \\
\text{where } n \geq m \geq n
\]

Given that we need the sonority hierarchy anyway, there can hardly be anything wrong with taking advantage of this option. But now we seem to have an embarrassment of riches: there still exists the standard way of distinguishing vowels from consonants.

This is embarrassing, of course, only to the extent that the standard feature system is empirically well-motivated and necessary for the specification of classes which cannot readily be specified with reference to the hierarchy. The features in question are the "major class features": + cons, + vocalic, and + obstruct.
together with whatever features are required to distinguish \( r \) from \( l \), \( y \) from \( y \), and \( h \) from everything else. We cannot here undertake

the indicated reexamination of this part of the standard feature system; we can, however, point out that the major class features in

the Chomsky-Halle system are, in distinction to the cavity, manner, and source features, conspicuously arbitrary, and that they are the

only ones not associated with a well-defined articulatory gesture; and that the features distinguishing among the "liquids" and "glides"

are conspicuously useless for other purposes, in general. What we will suggest here is that at least some of the distinctions that

have been described in terms of major class features and such minor features as [lateral] are in reality distinctions of rank along

the sonority hierarchy. We will outline here a set of specific proposals which embody several clearly testable claims; to the extent

that these claims are borne out by the facts, we believe that a theory which incorporates them must be preferred to one which does

not.

Our major proposal is that the major class features as defined

by Chomsky and Halle have no systematic significance, and that rules

which have been formulated in terms of them should be formulated with

reference to the sonority hierarchy. We also put forth a minor proposal that any feature which serves only to distinguish between

various liquids and glides should be removed from the feature inventory; we claim that such distinctions are in general distinctions

along the sonority scale, and that phonological rules treat them

as such. These assumptions immediately explain why the major class features seem arbitrary: it's because they are. And it is no mystery

why the features distinguishing \( r \) from \( l \) are ad hoc.

It is clear, of course, that the assignment of numerical ranks

provides a means of referring to every class which is ranked on

the hierarchy; and the 2 notation allows easy reference to certain combinations of those classes, namely adjacent ones. In fact,

since sonority according to our theory is a single multi-valued feature, we claim that these are the only classes referable to on

the basis of sonority; i.e. we do not allow the use of conjunctions of conditions to specify discontinuous reaches of the scale.

This proposal makes available a set of natural classes based

on the feature of sonority which coincides only partially with the

natural classes provided by the Chomsky-Halle feature system. It

allows easy reference to the class of fricatives and nasals, for

example, and to the class of nasals, liquids, and glides.

Underhill (1973) has shown that there are rules in natural

languages requiring reference to the following classes: stops + fricatives; fricatives + nasals; nasals + liquids; liquids + glides.

He observes that it is an inherent property of a universal

binary feature notation that it is in principle impossible for all of these classes to be natural; some of them will be difficult

to specify no matter what system of features is chosen. According to his results, this necessary consequence of the binary

feature representation is not in accord with the facts, and consequently the decision to represent major class distinctions in

terms of binary features is wrong in principle.

Note that the hill which exhibits a strictly cross-linguistic theory, and exact

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Another consequence was the region of the so-called language defines its

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3. Conclusion

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Note that the typology of natural classes discovered by Underhill which exhibits a progressive relation of affinity, rather than a strictly cross-classifying one, is exactly what is expected under our theory, and exactly what is not expected under the standard theory.

Another consequence of the theory proposed here is that in the region of the sonority scale between nasals and vowels, each language defines its own natural classes. Since the sonority ranking of liquids and glides is not universally fixed, we expect that the natural classes in this region will vary from language to language, but will be determined by the language-particular articulatory nature of the segments. So we predict that in some languages 1 and 2 will be adjacent on the hierarchy, and will pattern together, as opposed to 3 (as was found to be the case in Hungarian); however, we predict that in a language like Pali where 1 and 2 are non-adjacent (as shown by their assimilation behavior) there will be no rule referring to a class consisting of just 1 and 2, though there may be a rule referring to the class 1 v y 3. We claim, in effect, that there is no class of "liquids" in Pali.

The language-particular, as opposed to universal, specification of natural classes is a basic empirical difference between our theory and the standard feature system. The Chomsky-Halle feature system, for example, provides a natural means of referring to the class consisting of vowels + glides ([+ con]); and simultaneously a means of referring to the class of vowels + liquids ([+ voc]). Our theory claims that there will be no language in which both of these classes are "natural"; and there will be some in which neither is "natural." Pali is such a language.

It should be noted that our proposal does not affect those features which do have a definite articulatory basis of a binary (on-off) nature, and are needed independently of specifying major class distinctions. The oral and nasal stops, for example, frequently pattern together, i.e. act as a natural class. This class, however, is distinguished by the articulatory feature of complete oral closure, i.e. the feature [-continuant] in the standard system. This feature, in contrast to the major class features, has a genuinely binary articulatory characterization. Other clearly necessary binary features are nasality and voicing.

There is unfortunately not space in a paper of this scope to thoroughly explore the consequences of this proposal. The empirical claims involved, however, are quite clear, and we believe that what evidence there is is entirely in favor of our proposal over the standard feature system. If we are correct, the the major class features are nothing but an artifact of the decision to treat all phonological distinctions as binary.

3. Conclusion

In section 1 of this paper, we showed that the Pali CA rule refers to a hierarchical relation among segments, which seems to correspond to the traditional notion of sonority. In section 2, we proposed a formula for the representation of this relation so that rules can refer to it, and discussed the consequences of the
adoption of such a device. Our major conclusions are

(a) that the major class features of the standard feature
system do not exist; and

(b) that there is language-particular, rather than universal
determination of natural classes in the liquid-glide re-
region of the sonority scale.

Here we will briefly outline the major problems for the fur-
ther investigation of sonority. These problems arise mainly from
our inability to define sonority directly in phonetic terms, and
from the complexity of the interaction between sonority and other
factors in determining phonological regularities. Phenomena in
which sonority appears to play a role include syllable structure,
syllabicity phenomena, the determination of natural classes for
rules of certain types, phonological change, variability in rule
application, assimilation phenomena. Because of the abstract
nature of the sonority feature, the most interesting claims about
it will ultimately reduce to claims about congruences between as-
pects of these phenomena in a given language. It should be clear
that we are rather in a position of envisioning how this might be
done than doing it. What is required, and what we don't have, is
a highly developed theory of the various phenomena in which
sonority appears to surface (or worse yet, not surface).

Finally, we must mention the vast range of apparently hierar-
chical phenomena which might conceivably have something to do with
sonority, but we just can't tell. A typical example is the rule of
vowel contraction in Greek, where (under certain circumstances)
when two unlike vowels are adjacent, one of them deletes; and the
survivor is the one which is higher (toward a) on the hierarchy
[See, for example, Grammont (1965) for details.] Other
examples are various lenition and vowel-raising processes, which
occur both historically and synchronically, and which have long
been recognized as problematic for a theory requiring strictly bin-
ary feature representations.

It is clear that, as usual, the real task is before us. What
we have attempted to do in this paper is to open the door on a gen-
eral investigation of sonority-dependent phenomena, which we be-
lieve has heretofore been impeded by the general uncritical ac-
tenance of the standard system of binary distinctive features.

Footnotes

1 This assumption has been challenged, particularly with regard
to the specification of vowel height; see, for example, McCawley

2 The idea of such a hierarchy is far from new; it is presupposed
in Geiger (1915) in his discussion of the Pali assimilation; it is
discussed in Saussure (1916); the idea recurs throughout the pe-
riod of structuralist phonology, and evidence for its significance
has been presented in recent work by Foley (1970) (evidence from
phonological change), phenomena, Vennemann
ification phenomena).

3 Pali is the prakrit-
Ceylonese Buddhism, i.
B.C. The texts do not
mixture of Eastern and
maintain amount of complex
4 There are exceptions: the consonant assimilation
forms ideographsically part ignore these excep-
tion (1916) and Fischel
5 The consonant assimilation by Geiger (1916):
darstellung schafft die kraft
[See, for example, Grammont (1965) for details.] Other
examples are various lenition and vowel-raising processes, which
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9 This establishes the hierarchy of
(a) [l] [-c]
(b) [l] [-p]

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phonological change, Zwicky (1972) (evidence from fast speech
phenomena), Vennemann (1972), Hooper (1973) (evidence from syllabification
phenomena).

3 Pali is the prakrit in which the Tipitaka, the sacred book of
Ceylonese Buddhism, is written. It was spoken in the 6th century
B.C. The texts do not represent a unified dialect, but rather a
mixture of Eastern and Western dialects, which results in a cer-
tain amount of complexity.

4 There are exceptions to this: some suffixes were exceptions to
the consonant assimilation rule, and certain clusters in certain
forms idiosyncratically failed to geminate. We will for the most
part ignore these exceptional cases in this exposition; see Ge-
ger (1916) and Pischel (1900) for details.

5 The consonant assimilation rule was stated in essentially this
form by Geiger (1916): "...dass der Konsonant von geringerer
Widerstandskraft sich dem Konsonanten von stärkerer Widerstand-
kraft anlehnt. Die Widerstandskraft nimmt ab in der Reihe folgende
Nuten - Zischlaute = Nasale = l, l, r ... Wo Mute mit Nute oder
Nasal mit Nasal verbunden ist, assimilirt sich der erste Konso-
nant dem zweiten." (p. 68)

6 Vennemann (1972) and Hooper (1973) represent essentially the
same scale as a scale of "strength" and take the stops as occupying
the high end. No significance should be attached to our deci-
sion to treat the scale as a scale of sonority, increasing toward
r, rather than the inverse.

7 Zwicky (1972) formulates just such a set of "principles" to es-

dablish a hierarchy of sonority:

(a) [i] [-cons] precedes [+cons]
(b) [i] [-obst] precedes [+obst]
(c) [+vowel] precedes [-vowel]
(d) [+cont] precedes [-cont]

This establishes the hierarchy stops - fricatives - nasals - liquids
-glides - vowels, in order of increasing sonority. Another principle
([-ant] precedes [+ant]) places r higher than l. Hooper (1973)
also provides such a characterization.

8 John Ohala, in a paper also presented at this session, char-
acterized abstractions such as sonority which cannot (at our pre-
current state of knowledge) be defined directly in terms of phonetic
parameters, as "meaningless labels", and any phonological theory
which makes use of such abstractions as "crypto-taxonomic", indi-
cating that such a theory has abandoned all hope of real explana-
tion.

The assumptions underlying this claim are clearly indefensi-
ble: there is no explanatory theory known to science that does not
involve abstraction at some level, and if you follow the argument
to its logical conclusion it would deny explanatory to, for
example, all of syntactic theory (what are the directly observable
parameters defining the notion "noun phrase"?) and much of modern
physics (what is an electron other than an unobservable abstract entity which is posited within a theory designed to account for certain effects?) In fact, we believe that the science of phonetics, under careful scrutiny, would be seen to fall into the "cryptotaxonomic" class of sciences too.

We are indebted to Robert Vago for the information about Hungarian, and for several helpful suggestions.

There is unfortunately not space here for us to go into the complex relation of the notion of sonority to syllable structure. It is clearly not the case that sonority is the only parameter involved in the determination of syllable structure regularities, and it is also clear that the assumption alluded to in the text is far too simple, witness English beats, beast, and beasts. We believe, however, that a theory of syllable structure is constructible and that is must crucially make use of the notion of sonority, and that the outliness of such a theory are understood (see Venezmann 1972) and Hooper (1973) well enough that we would have to recognize the occurrence of final y1 or f1 clusters in Hungarian as counterexamples.

See Guille (1973) for a partial exposition of a theory of preferred syllable codas, based implicitly on a hierarchy of sonority. Of particular relevance here is that he establishes a markedness hierarchy of coda types based essentially on the sonority of the first element: the more sonorous the first element is, the more preferred the coda.

Bibliography

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