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Phonological models of sonority

Sonority is one of those central notions of phonological theory that are inevitably referred to in the analysis and discussion of various problems but are, at the same time, basically ill-defined, with an unknown basis somewhere in the vocalisation makeup or the phonological design of natural language. The purpose of this paper is to survey the phonological models that have been proposed and to evaluate them without, of course, pretending to be able to give decisive judgements. We readily admit that we have no adequate solution to the phonological modelling of sonority; however, we do not find this worrying, since we are not at all convinced that sonority actually has to be modelled in the phonology. It may well be that sonority has a solid phonetic basis whose outlines are not yet quite clear to us — discussion of this question remains for others. In this paper we first say a few words about sonority and point to a couple of very general problems related to it, then list briefly the phonological phenomena that involve sonority, finally we expatiate upon eight models proposed by adherents of various theories.

1 Sonority and some basic questions

The common core of different sonority scales as given in the literature looks as follows:

(1) **The sonority scale**

vowels
glides
liquids
nasals
fricatives
stops

Some of the problematic points pertaining to the scale are:

(i) It is not evident whether, within obstruents, voicing or stricture is more relevant, more precisely: how do voiced stops and voiceless fricatives relate to each other? The reason why this question has not been perceived as worrying is that within the range of phenomena that involve sonority, these two classes of obstruents never need to be compared. For instance, they are basically never adjacent in any word or morpheme, which makes it unnecessary to compare directly their position in the syllable structure. They also do not turn into each other immediately in the course of sound change, hence there is no need to ask whether such a change would be weakening or strengthening.

(ii) Since the sonority scale was worked out mainly on the basis of European languages, it is not clear where voicing values other than voicelessness and modal voice should be ranked (i.e., breathy voice, creaky voice).

(iii) Liquids are a problematic class in themselves in that the phonetic properties underlying their unity are by no means as evident as in the case of stops, fricative or nasals (Ladefoged & Maddieson 1996 : 243). Phonetic works often ignore such a class (e.g., Kassai 1994). From the point of view of sonority, however, this again has not been seen as a problem, given that the class of liquids is the class of consonants that has been identified on a phonological, rather than phonetic, basis — primarily their phonotactic properties. Yet it does not follow that their representation is generally unproblematic in phonological theory. It is because of this, as will be seen, that e.g., Rice (1992) is unable to locate trills in the sonority hierarchy.

(iv) Some subclassify vowels and establish a rank within their class in such a way that open vowels are more sonorous than close ones. Harris (1994 : 56), for one, assigns close vowels to the same class as glides.

2 Sonority-related phenomena

2.1 The syllable

2.1.1 The internal structure of the syllable

The idea that sonority plays a crucial role in defining possible and impossible syllables goes back to the 1860s (Laziczius 1963 : 147–150). There is rather general agreement on this in spite of theoretical debates on the modelling of sonority. Most generally, the sonority contour of a syllable is subject to the following principle:

(2) **Sonority Contour Principle**
The nucleus of the syllable is constituted by the element of highest sonority; going from the nucleus towards either boundary of the syllable, sonority must not rise.

This principle explains a high number of phonotactic constraints in many languages at a desirable level of generality. The literature on this question is huge, for a bird's-eye-view see Kenstowicz 1994, Blevins 1995, Törkenczy 1994.

2.1.2 The accessibility hierarchy

The sonority scale does not only predict in what order segments may come within a syllable, it also functions as a hierarchy of accessibility for nucleus, i.e., as an implicational hierarchy of the availability of segment types for syllable peak. It is not possible, for instance for there to be a syllabic nasal in a language that lacks syllabic liquids (Basbøll 1994), whereas the opposite is possible.

2.1.3 The syllable contact law

It has been convincingly demonstrated by Murray & Vennemann (1983), Vennemann (1988, etc.) that sequences of adjacent but heterosyllabic elements are also subject to sonority-related constraints. A syllable contact is preferred if the sonority of the final segment is higher than that of the first sg of the second syllable. Several historical changes can be explained with this principle, such as developments triggered or undergone by onset /j/ in the old Indo-European languages.

2.2 Weakening processes

Weakening processes, whether diachronic or synchronic, are frequently defined on a basis other than sonority, yet sonority-increase is always classified as weakening, whereas sonority-decrease as strengthening. It seems that sonority is an often tacitly assumed guiding principle in the classification of phonological processes in this category (see Lass 1984 : 177ff). The fact is that weakening processes have not yet been independently defined, despite numerous efforts. As long as this is so, it is of course a tautology to say that weakening processes involve sonority.[1]

2.3 Other phonological processes

There are phonological processes that clearly cannot be consistently described without reference to sonority but are not reducible to syllable-related regularities. One such phenomenon is found in Indic. In the transition from Old to Middle Indic, all consonant clusters were reduced to geminates (with the exception of nasal+stop clusters). It was the consonant of higher sonority that assimilated to the one with lower sonority in each case. The direction of the assimilation thus depended on the original order of the two segments. Examples are:[2]

(3) **Middle Indic consonantal assimilations**

SANSKRIT	PALI/PRAKRIT	GLOSS
progressive assimilation		
supyate	*suppati*	'sleeps'
cakra	*cakka*	'wheel'
ratri	*ratti*	'night'
vipra	*vippa*	'Brahmin'
vajra	*vajja*	'thunderbolt'
viklava	*vikkava*	'alarmed'
prajvalati	*pajjalati*	'ignites'
atman	*atta*	'self'
regressive assimilation		
karkaśa	*kakkasa*	'rough'
carcari	*caccari*	'kind of song'
arpita	*appita*	'entrusted'
kharjuri	*khajjuri*	'date-palm'
ulka	*ukka*	'meteor'
no change		
antara	*antara*	'interior'

[1] For a detailed discussion of this point, see Cser, in press.

[2] Masica 1991 : 173–177. Words are written as conventional, so *y*=[j], *c*=[ʧ], *v*=[w], *j*=[ʤ], *ś*=[ʃ].

This highly general change can indeed only be coherently described with reference to sonority, which, of course, also defines permitted syllables in the same language(s). The change itself, however, cannot be captured in terms of syllable structure.

3 Phonological models of sonority

3.1 Government Phonology

Phonological theories strive to express sonority within the internal structure of segments. In GP,[3] segments consist of phonetically interpretable elements, but are, strictly speaking, unstructured. Within the segment an asymmetrical relation can be defined over the elements which picks one as head and others as dependents. The elements can be phonetically interpreted in themselves in two different ways (vocalic and consonantal). They function similarly to unary features; no rule can make reference to their absence.

Stops contain the stop element (**ʔ**) in all cases, whose isolated manifestation is [ʔ] and whose salient feature is a sudden drop in acoustic energy. Fricatives always contain the noise element (**h**), whose isolated manifestation is either [h] or [s] and whose acoustic property is noise. In stridents **h** is the head, in non-strident fricatives it is an operator. Stops only contain the noise element if they are released. Contrastively voiced segments contain **L**, aspirated segments contain **H** — these are the two laryngeal elements.[4] Nasals contain both **N** (i.e., nasality) and **ʔ**. The representation of liquids is a matter of debate, but they surely do not contain noise or nasality. Glides have the same representation as the corresponding vowels.

So to what extent does GP capture sonority? Voiced obstruents are composed of more elements than their voiceless counterparts. Fricatives are composed of fewer elements than released stops and of the same number of elements as unreleased stops but the elements themselves are different in the latter case too (and head-operator relations are not the same either). Nasals contain one **N** more than unreleased stops. Liquids are composed of fewer elements than nasals.

[3] The comprehensive discussions which we have used are Szigetvári 1998 and Harris 1994. The earliest exposition of the theory is Kaye, Lowenstamm & Vergnaud 1985.

[4] For problems related to these two elements, see Szigetvári 1996.

Generally speaking, then, the composition of segments does not relate to sonority in any consistent fashion.[5] In some cases the content of a segment gets poorer with increasing sonority, as in the case of released stops and fricatives of the same phonation type. In other cases the content of a segment gets richer with increasing sonority, as in the case of voiceless vs. voiced obstruents or fricatives vs. nasals. Of course it must be borne in mind that in this theory the number of elements within a segment is determined by what is contrastive and what is not: redundant phonation features, for instance, will not be included within the representation.[6]

It is problematic that in some cases the complexity of segments, while inversely proportional to their sonority, is directly proportional to their typological frequency and correlated to their position in the implicational hierarchy of segment types. The relation of marked vs. unmarked segments is well captured in the case of nasals vs. stops, or the different phonation types of stops, but on the contrary with fricatives vs. stops, where stops, the most elementary consonants typologically, have a more complicated structure than fricatives, though the latter are rarer and are lower in the implicational hierarchy (i.e., fricatives imply the presence of stops in the system but not vice versa).

3.2 Dependency Phonology

In DP[7] distinctions of manner of articulation are encoded within the phonatory subgesture which is itself dominated in infrasegmental structure by the categorial gesture. The other subgesture within it is the initiatory subgesture, whose structure has not been worked out in as much detailed as that of its sister. Ewen (1995) already assigns all sonority-related features (i.e., basically all manner and major class features) to a single node. The (former) phonatory subgesture is composed of various combinations of two basic elements, maximal consonantality (|C|) and maximal vocalicness (|V|). These two can be represented more than once in any one instantiation and can be related symmetrically or asymmetrically. The major manner classes have the following representation:

[5] In spite of the fact that Harris (1990) explicitly criticises other theories for not representing sonority and the essential unity of lenition processes segment-internally.

[6] We mention in passing that sonority was meant to be encoded by the notion of charm in earlier versions of the theory. Charm, however, has not proved particularly useful and has tended to be neglected recently. See Szigetvári 1998 : 173f.

[7] See Anderson & Ewen 1987, Durand 1990 : 276–312, Ewen 1995.

(4)	Vowels:	V
	Liquids:	V>{V,C}
	Nasals:	V>C
	Voiced fricatives:	{V,C}>V
	Voiceless fricatives:	V,C
	Voiced stops:	C>V
	Voiceless stops:	C

The sign > points from head to dependent, the comma separates elements that are equal in the structure. As can be seen, the representations capture growing sonority by gradually assigning a more and more "dominant" position to the (|V|) element. It is also apparent that typological unmarkedness is related to the simplicity of the structure: the two most basic segment types, voiceless stops and vowels have the simplest, liquids and voiced fricatives the most complex phonatory subgesture.

These two properties of manner representations in DP follow from the fact that they were worked out precisely in order to encode sonority and markedness. It is, however problematic that in this way Dependency Phonologists are compelled to assign phonetically (and largely functionally) unrelated features to the same node. So what is the basis of their feature geometry?

> "One criterion for the grouping of features which is appealed to in dependency phonology, but which has been largely ignored in feature geometry [viz., of other theories — A.Cs.] is that a set of features which takes part in hierarchy-based processes should be considered to be part of the same group, or, in geometrical terms, to be dominated by a single node. This applies particularly to... the manner and major class features, which are involved in hierarchy-based processes such as weakening and relations such as syllabification" (Ewen 1995: 576).

In view of this it is not a merit of DP that it can represent sonority relations, since it cannot really represent anything else. Why should oppositions like stop vs. fricative, voiced vs. voiceless, nasal vs. oral be all expressed in the same node in a feature geometry? Furthermore, taking it for granted that the sonority scale defined by syllable structure is the same as that defined by weakening processes is an unwarranted simplification (fricatives never "weaken" into nasals etc.) and definitely not something that a theory should be based on.

3.3 Puppel's model

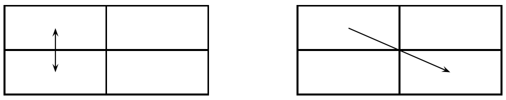
The basic insight of DP is developed further by Puppel (1992). He divides infrasegmental structure into a C- and a V-domain which are cross-cut by the Source (initiation, whose exponent is [voice]) and the Filter (articulation, [continuant]). The C-domain is characterised by a negative specification for both (i.e., a typical C is a voiceless stop), whereas for the V-domain they are positively specificied (i.e., a typical V is a voiced continuant). Thus the structure of a segment consists of the following four domains:

(5)

–	+	Filter
–	+	Source
C-domain	V-domain	

Puppel defines manner classes on the basis of what he calls preponderance (or headness) of one of the four domains. Where the head is C (i.e., in the case of stops), the preponderant domain is C-Filter:

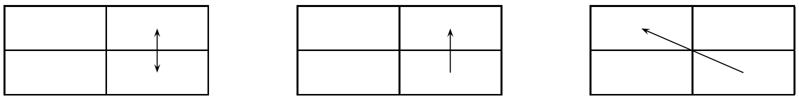
(6)



voiceless stop[8] (C) — voiced stop (C>V)

Where the head is V (i.e., in the case of sonorants), the preponderant domain is V-Source:

(7)

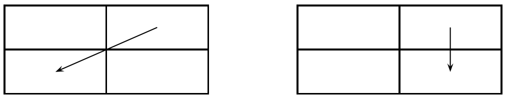


vowel (V) — liquid (V>{V,C}) — nasal (V>C)

Where the head is the combination V,C (i.e., in the case of fricatives), the preponderant domain is V-Filter:

[8] In fact, for voiceless stops and vowels there is not one preponderant domain. This is not explained by the author.

(8)



voiceless fricative (V,C) — voiced fricative ({V,C}>V)

By deriving manner classes, Puppel also derives sonority from the preponderance of one of the four domains. Actually only three of the four can be heads, but we never learn why the C-source domain cannot be preponderant within the segment. An even more worrying fact is that Puppel does not make it clear what his central notion, preponderance, consists in, although he explicitly claims it to be a phonetic property:

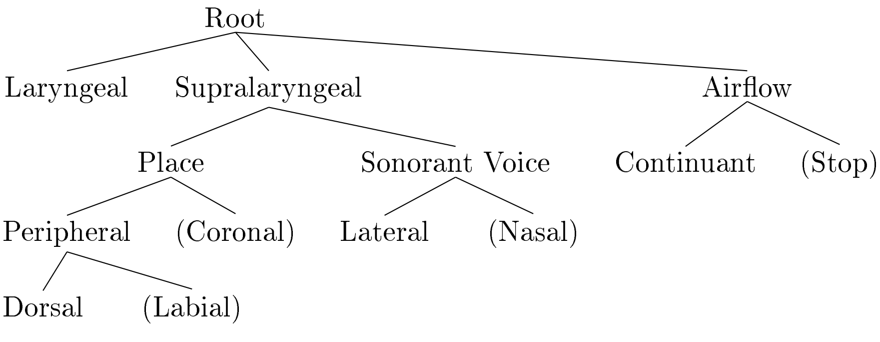
> "[A]ny possible arrangement of the segment types... into a ranking sequence necessarily involves the determination of the filter or source as head or as modifier. What it means in more phonetic terms is that in considering a particular segment type, one must first examine the filter characteristics such as the presence of occlusion or its absence, degree of constriction and corresponding presence or lack of turbulence, as well as the source characteristics such as the abducted state of the vocal folds... and then consider inter-dependencies between them" (Puppel 1992 : 472).

This is all we get as an explanation — not much to go by. In this light it is questionable if Puppel's model is really a model of sonority at all.

3.4 Rice's model

The model expounded in Rice (1992) is based on the assumption that sonority is directly proportional to the internal complexity of segments. The hypothesised feature geometry is the following:

(9)



The features in parentheses are default values under their nodes and are thus not represented: an empty Sonorant Voice node is automatically interpreted as Nasal, an empty Place node as Coronal etc. This is crucial for the model, since without underspecification segment types could hardly differ in the amount of "material" they consist of. Thus nasals have less structure than laterals, coronals than peripherals and stops than fricatives.[9] The unmarked character of coronals has been well known and amply discussed,[10] but markedness relations among manner classes are much less unequivocal. In order to argue for the unmarked status of nasals, Rice claims that they undergo but do not trigger assimilation and have less constrained distributions than other sonorants. The first argument is palpably false: nasality is a frequently spreading feature, and nasals usually undergo place, but not manner assimilation. The second argument is also ill-founded in our view. It is enough to point out that in English as well as Hungarian and Latin a branching onset may contain a nasal in second position only after a fricative, if at all (E *smile,* H *smúz* 'sycophantic talk'), whereas liquids can be found after almost all stops and one or two fricatives (E *clue, fly,* H *drága* 'expensive', *friss* 'fresh').

Rice also claims that evidence for this feature geometry comes from language acquisition and the implicational hierarchy of sound types. Due to our incompetence, we do not wish to say anything about the former, but we note that the literature known to us (e.g., Kovács 1993) shows a rather more complicated picture. As regards the implicational hierarchy, nasals are indeed higher than liquids in terms of phonation types, (as are stops with respect to fricatives). But even this consequence of the model is undercut by the fact that Rice is unable to assign trills any structure within the framework, even though in the implicational hierarchy trills appear to go hand in hand with laterals. It is also a weakness of the theory that it cannot integrate glides and vowels.

3.5 Basbøll's model

Basbøll (1994) derives sonority simply from the set-theoretic relation of inclusion, starting from the prototypical syllable-peak. This latter means vocoids, which are by necessity sonorants—hence the next class. Sonorants

[9] Even though Rice does not rank obstruents with respect to each other. To our knowledge, the undifferentiated treatment of obstruents goes back to Clements (1990).

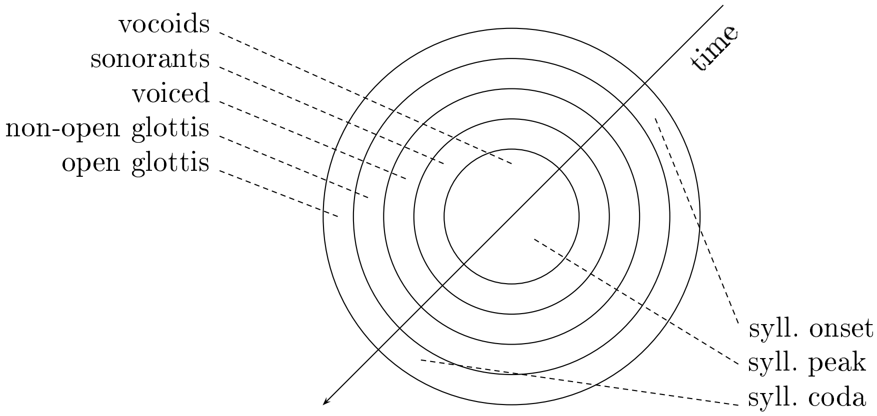
[10] See e.g., Paradis & Prunet 1991, Szigetvári 1994.

are universally voiced, voiced segments are a proper subset of non-open glottis segments, which are a subset of the largest set, that of segments. With this, Basbøll takes it that the sonority scale, whose independence from syllable structure he stresses, is given:

(10) vocoids
(non-vocoid) sonorants
(non-sonorant) voiced segments
(non-voiced) non-open glottis segments
open glottis segments

If we cut the sets through with the time axis, the model becomes dynamic and the sonority template of maximal syllable structure is obtained:

(11)



This, as Basbøll (1994 : 64) claims, is the only possible relation between the manner classes empirically as well as logically. This seems a bit far-fetched, as implied by the author himself when on the next page he considers the alternative hierarchy vocoid > sonorant > perceptually continuant > segment.

It is difficult to say anything about Basbøll's model since he gives no arguments for it, apart from a handful of well known commonplaces and generalities. With a slight change in the features we could get completely different sets and consequently a completely different sonority scale. Cutting through the sets with the time axis to obtain the syllable template seems nothing more than playing around with the graphic representation, hardly interpretable in any coherent theory.

3.6 Clements' model

Clements (1990) derives sonority from the +/− values the features [syllabic], [vocoid], [approximant] and [sonorant]. In Clements & Hume [syllabic] is dropped, with syllabicity reinterpreted as a prosodic configuration rather than a melodic feature. All features are underlyingly fully specified, so we get no differences in the amount of structure a segment has. The scale thus arrived at is the following (1995 : 269):

(12)

	[sonorant]	[approximant]	[vocoid]	sonority
obstruent	−	−	−	0
nasal	+	−	−	1
liquid	+	+	−	2
vocoid	+	+	+	3

As can be seen, sonority simply means the number of plus values for the three features. Clements (1985) and (1990) assign all three features to the supralaryngeal node, from which an interesting consequence follows:

> "By assigning the major class features to the supralaryngeal node rather than to the root node, we predict that laryngeal 'glides' — segments which only have laryngeal specification — are not ranked in any position on the sonority scale, and are not characterized for any major class features. This seems correct from a cross-linguistic perspective. Laryngeals tend to behave arbitrarily in terms of the way they class with other sounds…" (Clements 1990 : 322).

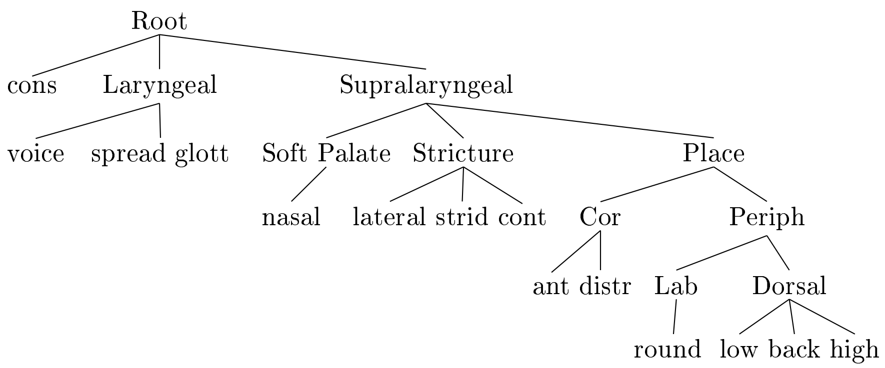
These (and only these) features are placed on the Root node in Clements & Hume (1995) — allegedly because they only spread in the case of total assimilation, not in themselves.

The weakness of the theory is that, since sonority is only defined by these features, which do not include, for instance, continuancy, Clements is also unable to sub-rank obstruents.

3.7 Dogil's model

In Dogil (1992) and Dogil & Luschützky (1990) sonority is inversely related to the internal complexity of segments. Their feature geometry is the following (Dogil 1992 : 330):

(13)



Sonority decreases with the increase in left-branching in the tree (i.e., the contrastive use of features on the left). For this they need underspecification, similarly to Rice (see **3.4**). In this model we get the following sonority scale:

(14) vowels
approximants
nasals
obstruents
laryngeals

It is noteworthy that the segments of lowest sonority are laryngeals, segments that only consist of a Laryngeal gesture. Nasals lack this gesture as compared to obstruents, approximants lack the Soft Palate gesture, while vowels lack Stricture. They regard the subclassification of these groups as possible but language-specific and so do not account for it in their model. Similarly to Rice's and dissimilarly to Clements', their model makes major class features unnecessary. Sonority-related phonological processes (syllabification in the first place) disregard feature specifications and are only sensitive to the structure of the tree.

The authors explicitly claim that this definition of sonority is phonetically grounded:

> "[S]onority is the degree of branchedness in the feature-structure. Notice, however, that this formal definition has straightforward substantive support. The sounds, the representations of which include more branches, automatically involve more components in their production, and, the more components involved, the less sonorant the sound is" (Dogil & Luschützky 1990 : 18).

This is, unfortunately, false because of underspecification. Phonetically speaking, the production of, for example, voicing is independent of its contrastivity, hence it is "substantively" the same in nasals and voiced fricatives. Phonologically different applications of individual articulators will not often be found to differ phonetically.

3.8 The model of Farmer Lekach and Kiparsky

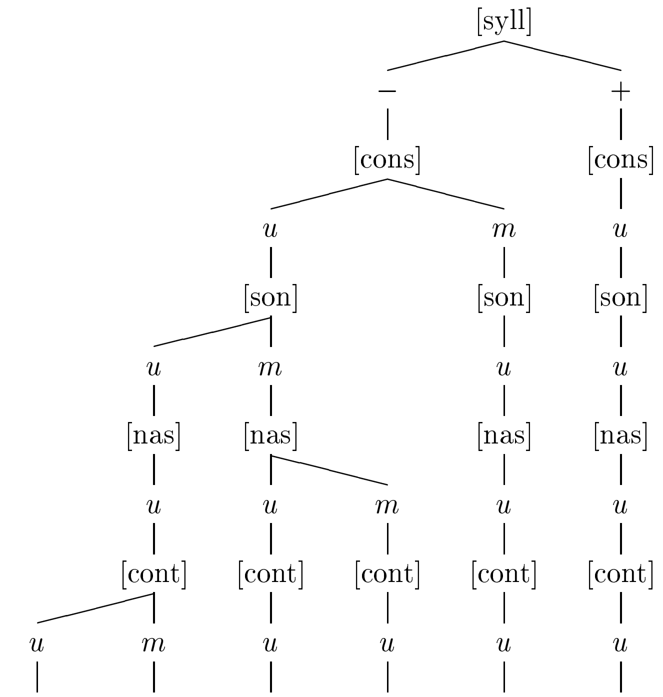
The model of sonority presented in Farmer Lekach 1979[11] and developed further in Kiparsky 1981 finds its roots in the first decade of generative phonology and is closely related to the underspecification theories seen earlier. In it major manner classes are defined by the hierarchically arranged features [syllabic], [consonantal], [sonorant], [nasal] and [continuant], which all have marked and unmarked values with respect to each other. The hierarchy of features and their individual values follow from the implicational hierarchy of segments. The way we arrive at the sonority scale is the following.

Topmost in the hierarchy is [±syllabic], followed by [±consonantal]. The unmarked value of the latter is [+] both with [−syllabic] and [+syllabic], its marked value ([−]) is only available with [−syllabic]. These two features then define the class of vowels ([+syllabic, *u* consonantal]),[12] glides ([−syllabic, *m* consonantal]) and "real" consonants ([−syllabic, *u* consonantal]). The next feature is [±sonorant], whose unmarked value is [−] with [+consonantal], [+] with [−consonantal]. This latter redundantly characterises vowels and glides, whereas within the class [+consonantal] the marked value distinguishes sonorants ([−syllabic, *u* consonantal, *m* sonorant]) from obstruents ([−syllabic, *u* consonantal, *u* sonorant]). The next feature is [±nasal]. Within obstruents, glides and vowels, it can only have the redundant unmarked value ([−]), within sonorants it can be unmarked ([+]) or marked ([−]). Thus we can differentiate between nasals ([−syllabic, *u* consonantal, *m* sonorant, *u* nasal]) and liquids ([−syllabic, *u* consonantal, *m* sonorant, *m* nasal]). The feature lowest in the hierarchy is [±continuant]. It can only have two values within the class of obstruents, in all other classes it has the unmarked value ([+] for nasals, [−] for the rest). For obstruents, [−] is unmarked, [+] is marked. The full matrices and their derivation are as follows:

[11] The author claims the model to be based on Kean's (1975) dissertation The Theory of Markedness in Generative Grammar, which I have not had access to.

[12] In these matrices *u* stands for unmarked, *m* for marked.

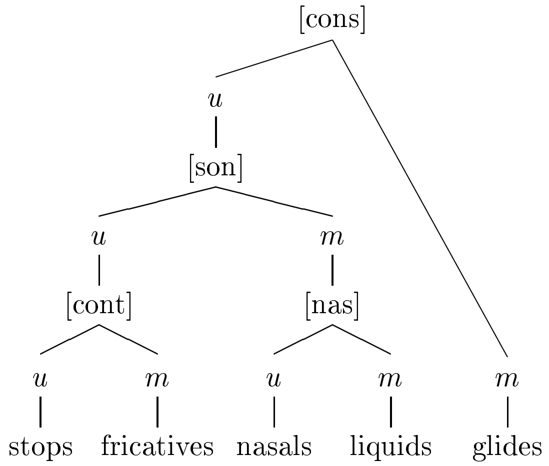
(15)



	stops	fricatives	nasals	liquids	glides	vowels
[syll]	−	−	−	−	−	+
[cons]	u	u	u	u	m	u
[son]	u	u	m	m	u	u
[nas]	u	u	u	m	u	u
[cont]	u	m	u	u	u	u

If the unmarked value always precedes the marked value in the tree, we get the sonority scale at the bottom from left to right. The higher a features has a marked value, the more sonorous the segment is. Kiparsky (1981 : 248) gives the tree in the following, somewhat simplified form:

(16)



As can be seen, markedness in this model is a relational term, that is, a given value of a given feature can only be marked or unmarked with respect to a given value of another feature. The only exception to this is [syllabic], which has no marked and unmarked values. This appears to capture the empirical fact that all languages have syllabic and nonsyllabic segments. The fact that [syllabic] is no longer a feature in phonological theory would not in itself undercut the validity of the model because it could, in principle, still hold for consonants.

There are, however, three serious shortcomings here. (i) No mention is made of phonation features, although the typological importance of phonation types can hardly be overemphasised. (ii) No arguments are given for this particular hierarchy of features. In this context one must remember what, among others, Steriade (1995 : 118f) says: redundancy relations within a segment can often be interpreted in two different ways. Voiceless obstruents, for instance, are unmarked both with respect to voiced obstruents and voiceless sonorants. (iii) The markedness statements made by the authors are of completely different weight. It is true that nasal vowels are marked with respect to nonnasal vowels but to claim that sonorants en bloc are marked in the same way with respect to obstruents is utterly disproportionate.[13]

[13] The reader should not be misled by the fact that nasal vowels are not included in the chart, since if they exist in a language, they cannot be otherwise represented than by branching [nasal] into marked and unmarked.

4 Conclusion

We hope to have given a useful survey of phonological models of sonority and we also hope that our critical remarks help the reader understand how difficult it is to adequately capture such an important and complex notion in any theoretical framework. In this paper we have played the devil's advocate; coming up with a solution of our own remains for another one.

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