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# *17*

# *The role of the sonority cycle in core syllabification*

G. N. CLEMENTS

## 17.1 Introduction

One of the major concerns of laboratory phonology is that of determining the nature of the transition between discrete phonological structure (conventionally, "phonology") and its expression in terms of nondiscrete physical or psycho-acoustic parameters (conventionally, "phonetics"). A considerable amount of research has been devoted to determining where this transition lies, and to what extent the rule types and representational systems needed to characterize the two levels may differ (see Keating 1985 for an overview). For instance, it is an empirical question to what extent the assignment of phonetic parameters to strings of segments (phonemes, tones, etc.) depends upon increasingly rich representational structures of the sort provided by autosegmental and metrical phonology, or upon real-time realization rules – or indeed upon some combination of the two, as many are coming to believe. We are only beginning to assess the types of evidence that can decide questions of this sort, and a complete and fully adequate theory of the phonetics/phonology interface remains to be worked out. A new synthesis of the methodology of phonology and phonetics, integrating results from the physical, biological and cognitive sciences, is required if we are to make significant progress in this area.

The present study examines one question of traditional interest to both phoneticians and phonologists, with roots that go deep into modern linguistic theory. Many linguists have noted the existence of cross-linguistic preferences for certain types of syllable structures and syllable contacts. These have been the subject of descriptive studies and surveys such as that of Greenberg (1978), which have brought to light a number of generalizations suggesting that certain syllable types are less complex or less *marked* than others across languages. We must accordingly ask how, and at what level these tendencies are expressed and explained within a theory of language.[1]

From the late nineteenth century onwards, linguists have proposed to treat generalizations of this sort in terms of a *Sonority Sequencing Principle* governing the preferred order of segments within the syllable. According to this principle, segments can be ranked along a "sonority scale" in such a way that segments ranking higher in sonority stand closer to the center of the syllable and segments ranking lower in sonority stand closer to the margin. While this principle has exceptions and raises questions of interpretation, it expresses a strong cross-linguistic tendency, and represents one of the highest-order explanatory principles of modern phonological theory.

A theory incorporating such a principle must give an adequate account of what "sonority" is, and how it defines the shape of the optimal or most-preferred syllable type. Up to now there has been little agreement on these questions, and phoneticians and phonologists have characteristically taken different approaches to answering them. Phoneticians have generally elected to focus their attention on the search for physical or perceptual definitions of sonority, while phonologists have looked for formal explanations, sometimes claiming that sonority has little if any basis in physical reality. It seems appropriate to reconsider these questions at this time, especially in view of the advances that have been made elsewhere in understanding syllable structure and its consequences for the level of phonetic realization.

My purpose here will be to examine the status of sonority within phonological theory. I will propose that an adequate account of sonority must be based on a principle termed the *Sonority Cycle*, according to which the sonority profile of the preferred syllable type rises maximally at the beginning and drops minimally at the end (the term *cycle* will be used exclusively in this study to refer to this quasiperiodic rise and fall). We will see that this principle is capable of providing a uniform explanation not only for cross-linguistic generalizations of segment sequencing of the sort mentioned above, but also for an impressive number of additional observations which have not been related to each other up to the present time. Regarding its substantive nature, I will suggest that sonority is not a single, multivalued property of segments, but is derived from more basic binary categories, identical to the major class features of standard phonological theory (Chomsky and Halle 1968) supplemented with the feature "approximant."

## 17.2 The Sonority Sequencing Principle: a historical overview

The notion that speech sounds can be ranked in terms of relative stricture or sonority can be found in work as early as that of Whitney (1865). However, the first comprehensive attempts to use such a ranking to explain recurrent patterns of syllable structure are due to Sievers (1881), Jespersen (1904), Saussure (1914), and Grammont (1933).

Sievers observed that certain syllable types were commonly found in languages, while others differing from them only in the order of their elements were rare or nonexistant. For example, he noted that *mla*, *mra*, *alm*, *arm* were relatively





frequent in languages, while *lma*, *rma*, ,
the liquids a higher degree of sonority
Sievers arrived at a ranking of speech
In a syllable consisting of several sou
termed the peak, or sonant, and the ot
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(1) 1. (a) voiceless stops, (b) voiceless
2. voiced stops
3. voiced fricatives
4. (a) voiced nasals, (b) voiced lat
5. voiced r-sounds
6. voiced high vowels
7. voiced mid vowels
8. voiced low vowels

Drawing on the work of Sievers a
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(2) *Sonority Sequencing Principle*:
Between any member of a syllable a
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Under this principle, given the sonorit
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## Principle: a historical overview

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frequent in languages, while *lma*, *rma*, *aml*, *amr* were not. On this basis he assigned the liquids a higher degree of sonority than the nasals. Proceeding in this fashion, Sievers arrived at a ranking of speech sounds in terms of their inherent sonority. In a syllable consisting of several sounds, the one with the greatest sonority is termed the peak, or sonant, and the others the marginal members, or consonants. According to Sievers' sonority principle, the nearer a consonant stands to the sonant, the greater must its sonority be.[2]

In Jespersen's version of the theory, which is the more familiar today, the sonority principle was stated as follows: "In jeder Lautgruppe gibt es ebensoviele Silben als es deutliche relative Höhepunkte in der Schallfülle gibt" ("In every group of sounds there are just as many syllables as there are clear relative peaks of sonority") (p. 188). Jespersen's version of the sonority scale is given in (1):[3]

(1)
1. (a) voiceless stops, (b) voiceless fricatives
2. voiced stops
3. voiced fricatives
4. (a) voiced nasals, (b) voiced laterals
5. voiced r-sounds
6. voiced high vowels
7. voiced mid vowels
8. voiced low vowels

Drawing on the work of Sievers and Jespersen, we may state a provisional version of the *Sonority Sequencing Principle* as follows:[4]

(2) *Sonority Sequencing Principle*:
Between any member of a syllable and the syllable peak, only sounds of higher sonority rank are permitted.

Under this principle, given the sonority scale in (1), syllables of the type *tra*, *dva*, *sma*, *mra* are permitted, while syllables like *rta*, *vda*, *msa*, *mla* are excluded. Cross-linguistic comparison supports the view that clusters conforming to the Sonority Sequencing Principle are the most commonly occurring, and are often the only cluster types permitted in a given language. Clusters violating this principle do occur, as we will see, but they are relatively infrequent, and usually occur only in addition to clusters conforming to it.

The theory of sonority just characterized was first developed in the late nineteenth century, when the notion of a synchronic grammar as a system of categories and representations defined at various degrees of abstraction from the physical data was yet to emerge in a clear way. The present revival of the sonority principle in phonological theory has taken place in a very different context, that of the initial period of response to Chomsky and Halle's *Sound Pattern of English*

(1968). Chomsky and Halle proposed, among other things, a major revision of the distinctive feature system of Jakobson, Fant and Halle (1952) which retained its binary character but reorganized the way sounds were classified by features. One aspect of the new system was a characterization of the traditional notion *degree of stricture*[6] in terms of a set of binary *major class features*. These features – first identified as [sonorant, consonantal, vocalic], with [vocalic] later replaced by [syllabic] – were grouped together on the basis of their similar function in accounting for the basic alternation of opening and closing gestures in speech (Chomsky and Halle 1968: 301–302). In terms of their function within the overall feature system, these features played a role analogous to that of sonority in prestructuralist phonology. By excluding any additional feature of sonority from their system, Chomsky and Halle made the implicit claim that such a feature was unnecessary.

The notion of *scalar* or multivalued features was first introduced into generative phonology by Foley (1970, 1972) as an alternative to binary feature systems. Foley's approach was intended as a radical alternative to the approach of Jakobson, Halle, and Chomsky. His main proposals were that (i) all binary features should be replaced by a set of scalar features, and that (ii) these scales do not refer to phonetic properties of segments, but are justified only by recurrent cross-linguistic aspects of segment behavior, as evidenced particularly in sound change. Foley's scalar feature of resonance (1972) is given in (3):

(3)
1. oral stops
2. fricatives
3. nasals
4. liquids
5. glides
6. vowels

Through its influence on Zwicky (1972), Hankamer and Aissen (1974), and Hooper (1976), all of whom cite Foley's work, this view of resonance gained wide currency and in its later adaptations came to have a substantial influence on the subsequent development of syllable theory within generative phonology.

More recently, the Sonority Sequencing Principle in something close to its original version has had a general revival in the context of syllable phonology (major references include Hooper 1976; Kiparsky 1979; Steriade 1982; and Selkirk 1984). In a significant further development, Hooper (1976) proposed a principle according to which the sonority of a syllable-final consonant must exceed that of a following syllable-initial consonant (equivalently, the second must exceed the first in "strength"). This principle, originally proposed for Spanish, has been found to hold in other languages, though usually as a tendency rather than an exceptionless law (Devine and Stephens 1977; Christdas 1988), and has come to





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(4) *The Syllable Contact Law*:
In any sequence $C_a \$ C_b$ there is a

## 17.3 Current is

In spite of its importance, sonority
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### 17.3.1 *At what level does th*

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be known as the Syllable Contact Law (Murray and Vennemann 1983). We may state it as follows, using $ to designate a syllable boundary:

(4) *The Syllable Contact Law*:
In any sequence $C_a$ $ $C_b$ there is a preference for $C_a$ to exceed $C_b$ in sonority.

## 17.3 Current issues in sonority theory

In spite of its importance, sonority remains an ill-defined, if not mysterious concept in many respects, hence the urgency of reexamining its theoretical and empirical bases.[6] Among the questions we would like to be able to answer are the following: how, exactly, is sonority defined in phonological theory? Is it a primitive feature, or is it defined in terms of other features? What are its phonetic properties? Assuming that some version of the Sonority Sequencing Principle is correct, at what linguistic level does it hold? Over what morphological or prosodic domain are sonority constraints most appropriately defined? Can we define a single sonority scale valid for all language, or must we recognize a significant degree of cross-linguistic variation? These are some of the questions that will be addressed in the remainder of this study.

### 17.3.1 *At what level does the Sonority Sequencing Principle hold?*

One important issue concerns the level at which the SSP holds. A surface-oriented version of the SSP might claim that it holds without exception of surface syllabification in all languages. In such a view, the SSP would project a unique and exhaustive syllabification over any arbitrary string of phonemes in surface representation, containing no prior annotations showing where the syllable peaks lie. In agreement with much of the more recent literature, I will suggest that such an interpretation of the SSP is incorrect, and that the SSP holds at a more abstract level than surface representation.[7]

Consider the representative examples in (5). The cases in (5a) represent sonority "plateaus," in which two adjacent consonants at the beginning or end of a word have the same sonority rank.[8] In (5b) we find representative cases of sonority "reversals," in which the sonority profile first rises, then drops again as we proceed from the edge of the word inward. As these examples show, reversals can be cited involving all major segment classes: fricatives, liquids, nasals and glides. In (5c) we find cases in which the syllable peaks are not sonority peaks (at least not prior to the assignment of syllabicity), but are adjacent to elements of higher sonority. For example, the syllabic peak of English *yearn* is the liquid [r], which is adjacent to the glide [y] and thus does not constitute a sonority peak. Contrasting examples such as *pedaller*, *pedlar* show that syllable peaks are not fully predictable in all languages on the basis of the surface context. The level of representation assumed here is approximately that of systematic phonetic representation prior to the application of (automatic or language-particular) phonetic realization rules, though as transcription practices vary from one writer to another and are often inexplicit, this assumption may not accurately reflect each writer's intention in all cases.[9]

(5) a. *Consonant sequences with sonority plateaus:*
English: apt, act, sphere
Russian: mnu 'I crumple', tkut 'they weave', kto 'who', gd'e 'where'
Mohawk: tkataweya't 'I enter', kka:wes 'I paddle'
Marshallese: qqin 'to be extinguished', kkɛn 'to be invented', lliw 'angry'

b. *Consonant sequences with sonority reversals:*
English: spy, sty, sky, axe, apse, adze
German: Spiel 'game', Stein 'stone', Obst 'fruit', letzt 'last'
Russian: rta 'mouth (gen.)', lba 'forehead (gen.)', mgla 'mist'
French: table [tabl] 'table', autre [otr] 'other'
Cambodian: psa: 'market', spiy 'cabbage'
Pashto: wro 'slowly', wlar 'he went', lmar 'sun'
Ewe: yra 'to bless', wlu 'dig'
Klamath: msas 'prairie dog', ltewa 'eats tules', toq'lca 'stops'
Mohawk: kskohárya'ks 'I cut dead wood'
Ladakhi: lpəks 'skin', rtiŋ-pɔ 'heel', rgyəla 'road'
Kota: anžrčgčgvdk 'because will cause to frighten'
Abaza: yg'yzdmlrətxd 'they couldn't make him give it back to her'
Tocharian A: yneś 'apparent', ysar 'blood'
Yateé Zapotec: wbeγ 'hoe', wše-zi-le 'morning', wza-'a 'I ran'

c. *Syllables whose peaks are not sonority peaks:*
English: yearn [yr̩n], radio, pedaller [ped-l̩-r̩] vs. pedlar [ped-lr̩]
German: können [køn-n̩] 'to be able', wollen [vol-n̩] 'to be willing' vs. Köln [køln] 'Cologne'
French: rel(e)ver [rə-l̩-ve] 'to enhance', troua [tru-a] '(s)he dug a hole' vs. trois [twa] 'three', haï [a-i] 'hated' vs. ail [ay] 'garlic'
Spanish: país [pa-is] 'country', río [ri-o] 'river', bahía [ba-i-a] 'bay'; fuimos [fwi-mos] 'we went' vs. huimos [u-i-mos] 'we fled'; piara [pya-ra] 'herd' vs. piara [pi-a-ra] 'chirp' (past subj.)
PIE: *wl̩kos 'wolf' (cited by Saussure as evidence against the sonority theory)
Turkish: daǧa [da-a] 'mountain (dat.)' vs. daǧ [da:] 'mountain' (nom.)
Berber: ti-wn̩-tas 'you climbed on him', ra-ymm̩-yi 'he will grow', ra-tk̩-ti 'she will remember'
Swahili: wa-li-m̩-pa 'they gave him', wa-i-te 'call them', ku-a 'to grow' vs. kwa 'of, at'
Luganda: ttabi [t-tabi] 'branch', kkubo [k-kubo] 'path', ddaala [d-da:la] 'step'
Bella Coola: nm̩nmak 'both hands', mn̩mn̩ts 'children', sk'lxlxc 'I'm getting cold'

The facts are not at issue in most of these cases, and in many similar cases that





could be cited. Some writers' accounts
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Van Valin (1982) report that the glide
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a rapidly moving second formant; (ii) [u
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rehead (gen.)', mgla 'mist'
otr] 'other'
bage'
t', lmar 'sun'

eats tules', toq'loa 'stops'
wood'
rgyala 'road'
use to frighten'
make him give it back to her'
blood'
le 'morning', wza-'a 'I ran'
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re as evidence against the sonority theory)
t.)' vs. dağ [da:] 'mountain' (nom.)
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', wa-i-te 'call them', ku-a 'to grow' vs.

ubo [k-kubo] 'path', ddaala [d-da:la]

mnmnts 'children', sk'lxlxc 'I'm getting

hese cases, and in many similar cases that





could be cited. Some writers' accounts are detailed enough to allow us to accept the transcriptions with a very high degree of confidence. For example, Jaeger and Van Valin (1982) report that the glide [w] occurs regularly before obstruents in word-initial clusters in Yateé Zapotec (see examples in (5b) above). They argue that [w] cannot be reanalyzed as or derived from the vowel [u] for a number of reasons: (i) [w] has the acoustic properties of a glide, namely short duration and a rapidly moving second formant; (ii) [u] does not occur elsewhere in the language, underlyingly or on the surface; (iii) otherwise there are no vowel-initial words in Yateé Zapotec; (iv) [w] carries no tone, whereas all syllables otherwise have phonemic tone; (v) [w] usually functions as an aspect prefix, and all other aspect prefixes are consonants. As Jaeger and Van Valin point out, this latter fact helps to explain the survival of these rare cluster types, since the [w] carries essential morphological information that would be lost if [w] were deleted.

Such problems for surface-oriented versions of the SSP were recognized in the earliest literature. Sievers, for example, noted the existence of anomalous clusters such as those in *pta*, *kta*, *apt*, *akt* in which the second member was a dental sound. He suggested that they might be due to the "ease of the articulatory transition" to a dental, but did not offer independent reasons for assuming that transitions to dentals were simpler than transitions to other places of articulation. Sievers had similar trouble dealing with the reversed-sonority clusters in syllables like *spa*, *sta*, *aps*, *ats*, and attempted to explain them by introducing the notion of the "secondary syllable" (*Nebensilbe*), a unit which counted as a syllable for the purposes of the SSP but not for linguistic rules, such as stress placement and the like. Jespersen proposed special principles to account for type (5c) violations involving *rising* sonority ramps (as in Spanish *río*), but had nothing to say about falling ramps (as in Spanish *país*).

I will suggest that the SSP holds at deeper levels of representation than surface representation, and in particular that it governs underlying syllabification in the lexical phonology. More exactly, the underlying representations of any language are fully syllabified in accordance with certain principles of *core syllabification*, which are sensitive to sonority constraints (see further discussion in section 17.5.1). However, some consonants remain unsyllabified (or *extrasyllabic*) after the core syllabification rules have applied. Such consonants either become syllabified at a later point in the derivation, or are deleted.

Such an analysis is strongly supported when we examine the phonological characteristics of sonority violations more closely, since we often find convincing evidence that they involve consonants that are not incorporated into syllable structure in the early stages of phonological derivations. In Sanskrit, for example, such consonants regularly fail to participate in reduplication, a fact which can be explained on the assumption that unsyllabified consonants are invisible to reduplication (Steriade 1982). In Turkish, Klamath, and Mohawk, among other languages, such consonants regularly trigger the application of a variety of epenthesis rules (Clements and Keyser 1983; Michelson 1988); we can view these rules as having the function of incorporating unsyllabified consonants into syllable structure, and thus of simplifying representations. The fact that extra-syllabic elements tend to be removed from representations by rules of epenthesis is an instance of the more general principle that rules tend to apply in such a way as to replace complex representations with simpler ("euphonic," "eurhythmic") ones. Furthermore, in English and many other languages, violations of the sonority constraints are restricted to the edges of the syllabification domain, reflecting the preference of extrasyllabic elements for this position (Milliken 1988). Thus, for example, the sonority violation found in the final cluster of *apt* can be explained on the assumption that the [t] is extra-syllabic at the point where the sonority constraints apply; notice that syllable-final sequence [pt] is found only at the end of level 1 stems, which form the domain of core syllabification (Borowsky 1986). Finally, there is evidence that such consonants may remain unsyllabified all the way to the surface, in a number of languages which permit long, arbitrary strings of consonants in surface representation (see examples in (5b) and the references just below).

Other, related ways of explaining or eliminating surface exceptions to the SSP have been proposed in the earlier literature. These include the restriction of the principle to the syllable "core" as opposed to "affix" (Fujimura and Lovins 1978), the recognition of a syllable "appendix" that lies outside the scope of sonority restrictions (Halle and Vergnaud 1980), the postulation of language-particular rules that take precedence over the principle (Kiparsky 1979, 1981), and the treatment of clusters such as English *sp*, *st*, *sk* as single segments rather than clusters for the purposes of syllabification (Selkirk 1982). It is not always possible to find convincing independent evidence for such strategies in all cases, however, and it seems possible that a hard core of irreducible exceptions will remain. Languages exhibiting a high degree of tolerance for long, arbitrary sequences of consonants prominently include (but are not limited to) the Caucasian languages, several Berber dialects, numerous Southeast Asian languages and many languages native to the Northwest Pacific Coast.[10]

### 17.3.2 *The phonetic basis of sonority*

A further issue in sonority theory involves its phonetic basis. Given the remarkable similarity among sonority constraints found in different and widely separated languages, we might expect that sonority could be directly related to one or more invariant physical or psychoacoustic parameters. However, so far there exists no entirely satisfactory proposal of this sort. The problem is due in part to lack of agreement among phonologists as to exactly what the universal sonority hierarchy consists of. As Selkirk points out (1984), it will not be possible to determine the exact phonetic character of sonority until phonologists have come to some





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Lindblom (1983) and Keating (198
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up with any way of measuring son
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motivated sonority scale.[11] The ultim
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esentations by rules of epenthesis is an
at rules tend to apply in such a way as to
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er languages, violations of the sonority
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this position (Milliken 1988). Thus, for
the final cluster of *apt* can be explained
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al sequence [pt] is found only at the end
of core syllabification (Borowsky 1986).
onants may remain unsyllabified all the
ages which permit long, arbitrary strings
see examples in (5b) and the references

iminating surface exceptions to the SSP
ure. These include the restriction of the
osed to "affix" (Fujimura and Lovins
pendix" that lies outside the scope of
ud 1980), the postulation of language-
the principle (Kiparsky 1979, 1981), and
*sp*, *st*, *sk* as single segments rather than
(Selkirk 1982). It is not always possible
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agreement about the identity of the hierarchy. But many proposals have been put forward at one time or another, and at present there are a great number of competing sonority scales to claim the attention of phoneticians.

This problem should disappear as better theories of sonority are developed. But in addition to uncertainty regarding the *linguistic* definition of the sonority scale, there is some question whether a uniform, independent phonetic parameter corresponding to sonority can be found, even in principle. This because the various major classes of speech sounds have substantially different properties from nearly every point of view: aerodynamic, auditory, articulatory, and acoustic. It is true that a variety of phonetic definitions of sonority have been offered in the past, from the early proposal to define it in terms of the relative distance at which sounds could be perceived and/or distinguished (O. Wolf, cited by Jespersen 1904: 187) to a variety of more sophisticated recent suggestions (see for example Lindblom (1983) and Keating (1983) for discussion of an articulatory-based definition of sonority, and Price (1980) for discussion of an acoustic-based definition). But as Ohala and Kawasaki state (1985: 122), "no one has yet come up with any way of measuring sonority" – not at least a widely agreed-upon method based on a uniform phonetic parameters corresponding to a linguistically-motivated sonority scale.[11] The ultimate response to this problem may be to deny that sonority has any regular or consistent phonetic properties at all (Hankamer and Aissen 1974; Hooper 1976; Foley 1977). While this represents a position to which we might be driven out of necessity, we do not choose it out of preference, since in the absence of a consistent, physical basis for characterizing sonority in language-independent terms we are unable to explain the nearly identical nature of sonority constraints across languages.

We should not be overly concerned about the difficulty of finding well-defined phonetic definitions of sonority, however. In the past, attempts to define linguistic constructs in terms of physical definitions (or operational procedures) have usually proven fruitless, and it is now widely agreed that abstract constructs are justified just to the extent that they are tightly integrated into the logical structure of predictive and explanatory theories. Thus, no adequate phonetic definition has ever been given of the phoneme, or the syllable – and yet these constructs play a central and well-understood role in modern phonology. Similarly, the notion of sonority is justified in terms of its ability to account for cross-linguistic generalizations involving phoneme patterning, and need not have a direct, invariant expression at the level of physical phonetics. The problem raised by our (at present) incomplete physical understanding of sonority reduces to the problem of accounting for why linguistically-motivated sonority rankings are very much the same across languages. I will suggest that the sonority scale is built into phonological theory as part of universal grammar, and that its categories are definable in terms of the independently-motivated categories of feature theory, as discussed in section 4.

### 17.3.3 *The redundancy of the feature "sonority"*

A further issue concerns the feature characterization of sonority. A multivalued feature of sonority makes good sense as an alternative to the binary major class features of standard theory, but is harder to justify as a supplement to them, since sonority can be adequately defined in terms of these independently-motivated features (see discussion below), and is thus redundant in a theory containing them. One way of eliminating this redundancy is to eliminate the major class features themselves. This approach is considered by Selkirk, who suggests that the work of the major class features can done by (a) a feature representing the phonetic dimension of sonority, (b) the sonority hierarchy, and (c) the assignment of a sonority index to every segment of the language (1984: 111). Hankamer and Aissen are even more categorical, stating "the major class features of the standard feature system do not exist" (1974: 142). Most proponents of the sonority hierarchy have been reluctant to go this far, but there has been little explicit discussion of how we may justify the presence of two types of features with largely overlapping functions in feature theory.

## 17.4 The major class features and the definition of sonority

On the basis of this review of the issues, let us consider how sonority can be incorporated into a formal theory of phonology and phonetics.

As has previously been noted (Basbøll 1977, Lekach 1979), the sonority scale can be defined in terms of independently-motivated binary features. I will adopt a definition involving the four major class features shown in (6), where O = obstruent, N = nasal, L = liquid, G = glide (the choice of this particular scale will be justified below). The sonority scale for nonsyllabic elements is derived by taking the sum of the plus-specifications for each feature.

(6)

| O < | N < | L < | G | |
|---|---|---|---|---|
| − | − | − | − | "syllabic" |
| − | − | − | + | vocoid |
| − | − | + | + | approximant |
| − | + | + | + | sonorant |
| 0 | 1 | 2 | 3 | rank (relative sonority) |

Three of these features are familiar from the earlier literature. "Syllabic" can be interpreted as referring to the prosodic distinction between V and C elements of the timing tier, or alternative characterizations of syllable peaks in prosodic terms. For reasons given in Clements and Keyser (1983: 8–11, 136–7), I will take this feature to have no intrinsic physical definition, but to be defined in language-





particular terms: "syllabic" segments ar
syllabic nucleus in any particular langu
those which do not. "Vocoid," a term
converse of the traditional feature "cc
"Sonorant" has its usual interpretation

In order to complete our definition
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The recognition of *approximant* as
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is an oral sonorant, i.e. an approximant
often pattern together. In Luganda, on
thus we find geminate /pp, bb, ff, vv,

We will treat *approximant* as a binary
In Ladefoged's account (see Ladefo
*approximant* is not a feature category, l
category *stop*. This category is a three-v
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*approximant* are mutually exclusive, an
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Keyser (1983: 8–11, 136–7), I will take
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particular terms: "syllabic" segments are those which attract the properties of the syllabic nucleus in any particular language, while "nonsyllabic" segments are those which do not. "Vocoid," a term introduced by Pike (1943), is simply the converse of the traditional feature "consonantal" and is defined accordingly. "Sonorant" has its usual interpretation.

In order to complete our definition of the sonority scale in terms of binary features we require a further feature, grouping liquids, glides and vowels into one class and nasals and obstruents into another. This is exactly the function of the feature "approximant," proposed by Ladefoged (1982) who defines it as "an articulation in which one articulator is close to another, but without the vocal tract being narrowed to such an extent that a turbulent airstream is produced" (1982: 10). In order to clearly exclude nasals (which do not involve a turbulent airstream), I will consider an approximant to be any sound produced with an oral tract stricture open enough so that airflow through it is turbulent only if it is voiceless.[12]

The recognition of *approximant* as a feature is justified by the fact that approximants tend to pattern together in the statement of phonological rules. For example, many languages allow complex syllable onsets only if the second member is an oral sonorant, i.e. an approximant in our terms. Similarly, nonapproximants often pattern together. In Luganda, only nonapproximants occur as geminates: thus we find geminate /pp, bb, ff, vv, mm/, etc., but not /ww, ll, yy/.

We will treat *approximant* as a binary feature, like the other major class features. In Ladefoged's account (see Ladefoged 1982: 10, 38–9, 61–2, 256, 265), *approximant* is not a feature category, but a value or specification of the feature category *stop*. This category is a three-valued scalar feature whose values are *stop*, *fricative*, *approximant*. This system makes the prediction that the values *stop* and *approximant* are mutually exclusive, and thus do not allow any segment to bear both of these values at once. The crucial data here involve laterals, which in the feature classification given in Halle and Clements (1983) are classified as [−cont], and in the present account must also be [+approximant]. Under the view proposed here, then, /l/ is both a stop and an approximant, and may function as such in one and the same language. This appears to be correct. For example, in English /l/ functions with the other approximants in its ability to occur as the second member of complex syllable onsets: /pl, tr, kw/, etc., while nasals may occur in this position only after /s/. But /l/ also patterns with nasals in the rule of intrusive stop formation, in which an intrusive stop is inserted between a nasal or lateral and the following fricative in words like *den[t]se, fal[t]se, ham[p]ster, weal[t]thy*. This rule involves a "lag" of the features [−cont] and [place] onto the following segment (see Clements 1987a for discussion).

The scale in (6) is incomplete in that it only provides for nonsyllabic segments, and not for syllabic segments, including vowels. In some languages, nasals and even obstruents can function as syllable peaks, in certain circumstances (for syllabic obstruents see Bell's 1978 survey article; Dell and Elmedlaoui 1985 for discussion of a dialect of Berber; Clements 1986 for discussion of syllabic geminates in LuGanda; and Rialland 1986 for discussion of syllabic consonants derived through compensatory lengthening in French). In principle, any segment can occupy the syllable peak, but the ability of a given segment to function as a syllable peak is related to its rank on the sonority scale. Our model predicts the following ranking of syllabic segments:

(7)

| O < | N < | L < | V | |
|---|---|---|---|---|
| + | + | + | + | syllabic |
| − | − | − | + | vocoid |
| − | − | + | + | approximant |
| − | + | + | + | sonorant |
| 1 | 2 | 3 | 4 | rank |

(Note that a syllabic glide is identical to a vowel, or to put it another way, a glide is simply a nonsyllabic vowel: cf. Pike 1943.) However, this does not quite accord with the facts, since as Bell has noted (1978), syllabic nasals are generally preferred to syllabic liquids in languages that have just one or the other. The notion "relative sonority," as defined in (7), does not therefore extend unproblematically to syllable peaks, which require separate discussion.[13]

In an alternative proposal, Van Coetsem (1979) has suggested reintroducing the feature "vocalic" alongside "syllabic." As he points out, this would correctly allow us to distinguish nasals and liquids by a major class feature, unlike the SPE feature system which must make use of the feature "nasal." In our proposal (and Ladefoged's), however, this task is accomplished by the major class feature "approximant." The major difference between the two proposals is that if we chose "vocalic" instead of "approximant," glides would be ranked at the same sonority level as liquids by the algorithm given above:

(8)

| O < | N < | L = | G < | V | |
|---|---|---|---|---|---|
| − | − | − | − | + | syllabic |
| − | − | − | + | + | vocoid |
| − | − | + | − | + | vocalic |
| − | + | + | + | + | sonorant |
| 0 | 1 | 2 | 2 | 4 | rank |

More importantly, a system with the feature "approximant" seems to reflect natural groupings of sounds better than one with "vocalic." Thus, liquids and glides ([+approximant] nonsyllabics) frequently fall together as a class in the statement of rules, while obstruents, nasals and glides ([−vocalic] nonsyllabics) rarely or never do. One of the primary functions of the feature [vocalic] in earlier feature systems was to designate the natural class of liquids, characterized as [+vocalic, +consonantal] sonorants. However, this function is equally well





served by a feature system contai
designated by the features [+approx
the major class features are correctl
Combinations of major class featu
non-occurring, and are excluded by

(9) a. [−sonorant] → [−approximant
b. [−approximant] → [−vocoid]

These rules entail the following, by

c. [+approximant] → [+sonorant
d. [+vocoid] → [+approximant]

I will assume that these redundancy r
rule as well-formedness conditions,
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The four major class features toge
define 21 natural classes (or 29, if v
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Terms that can be enclosed in a
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(10)

[+syllabic]: O

[−syllabic]: O

The three boxes represent the class o
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This shows that [syllabic] has a diffe
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ıwever, this function is equally well



served by a feature system containing [approximant], in which liquids are designated by the features [+approximant, −vocoid]. I conclude, therefore, that the major class features are correctly represented as in (6) and (7).

Combinations of major class features other than those given in (6) and (7) are non-occurring, and are excluded by the following universal redundancy rules:

(9) a. [−sonorant] → [−approximant]
b. [−approximant] → [−vocoid]

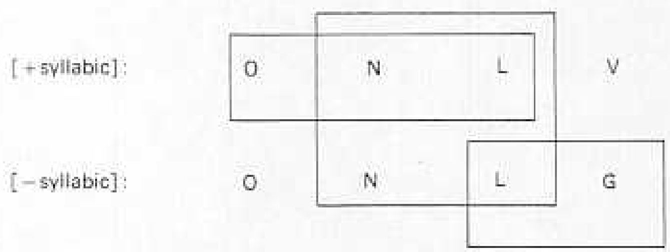
These rules entail the following, by contraposition:

c. [+approximant] → [+sonorant]
d. [+vocoid] → [+approximant]

I will assume that these redundancy rules apply to the output of each phonological rule as well-formedness conditions, and readjust the values for approximant, vocoid and sonorant as necessary.

The four major class features together with the redundancy rules given above define 21 natural classes (or 29, if we count single-member classes). These are conveniently suggested in terms of the following 2 × 4 array of segment types. Terms that can be enclosed in a vertically or horizontally oriented rectangle constitute a natural class. Three examples are given for illustration.

(10)




The three boxes represent the class of syllabic consonants, the class of consonantal sonorants, and the class of nonsyllabic approximants, from upper left to lower right. Notice that a single step to the right or up results in one-degree increase in sonority rank. This array clearly shows the special status of the feature [syllabic] in the sonority scale: it is the only major class feature that crossclassifies all others. This shows that [syllabic] has a different status in feature representation than the true major class features, not functioning as a feature but as a prosodically defined position within the syllable, as suggested above.

The sonority scale as given in (6) and (7) does not include a subdivision of obstruents into stops and fricatives, or into voiceless and voiced obstruents; nor does it recognize a distinction between lateral and central liquids. This is because to date (see further discussion below), the best-motivated cross-linguistic generalizations involving sonority, such as Greenberg's, do not appear to require any further subdivision of the sonority scale. However, some individual languages have been proposed as motivating further subdivisions, such as one between voiced fricatives and other obstruents, or one between lateral and central liquids. To accommodate such languages, linguists have proposed to recognize more elaborate versions of the sonority scale including additional features such as [continuant], [voiced], [coronal], etc., and have proposed that the features relevant for the definition of sonority can vary from one language to another. This approach will not be adopted here, however. The explanatory value of sonority theory lies in its ability to predict valid cross-linguistic generalizations. As soon as we allow the sonority scale to vary in its identity from one language to another, we seriously undermine its explanatory role by increasing the number of ways in which it will accommodate potential exceptions, thus reducing the number of cross-linguistic generalizations that it accounts for.

I will argue below that there are considerable advantages to maintaining a strong, predictive version of sonority theory. Much of the apparent evidence for language-particular variation in the sonority scale comes from observations which can be explained in other ways. For example, the tendency for voiced fricatives to be excluded as the first member of initial clusters, found in a number of languages including English, can be understood in terms of a principle (to be described in section 5.3) which holds that all else being equal, sequences containing less marked segments are favored over sequences containing more marked segments. Cross-linguistically, voiced fricatives are more marked than either stops or voiceless fricatives. This principle extends to many other distributional regularities that had previously been thought to require language-particular modifications of the sonority scale, such as the apparently greater sonority of coronal as opposed to noncoronal consonants in some languages. The strongest position consistent with the available evidence is that a single scale, perhaps O < N < L < G < V or a simple variant of this, defines the unmarked order of segments within the syllable across languages, and that apparent deviations from this scale have independent explanations.

### 17.4.1 *An alternative view: sonority as a multivalued feature*

What has tempted many linguists to consider sonority to be a single, multivalued feature is the fact that it arrays segment classes into a *hierarchy*. Other binary features in phonology do not seem to have this property. The notion of hierarchy, it can be argued, is most simply and directly expressed in terms of a single multivalued feature, rather than by making use of several binary features constrained by redundancy rules such as those in (9a–d). A multivalued feature of this sort is equally capable of capturing the necessary natural classes, if we allow





that rules may refer to any continuou
For example, given the sonority scale
glides and vowels can be referred to by
1972, Selkirk 1984 for discussion of s

Let us consider the notion of hierar
system, a hierarchy is defined whenev
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implication: [+F] → [+G] (entailing
a three-term hierarchy over the segm

| (11) | A | B | C | |
|---|---|---|---|---|
| | – | – | + | [F] |
| | – | + | + | [G] |
| | 0 | 1 | 2 | rank |

The number of terms in the hierarchy
Thus, the four-term hierarchy O < N
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Hierarchies of this type are comm
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that rules may refer to any continuous sequence of positions along the hierarchy. For example, given the sonority scale in (6) and (7), the natural class of liquids, glides and vowels can be referred to by the expression "[2–4 sonority]" (cf. Zwicky 1972, Selkirk 1984 for discussion of such a proposal).

Let us consider the notion of hierarchy in general terms. Given a binary feature system, a hierarchy is defined whenever we have an implicational relation holding between two features. For example, given the two binary features F, G and the implication: $[+F] \rightarrow [+G]$ (entailing $[-G] \rightarrow [-F]$ by contraposition), we define a three-term hierarchy over the segment classes A, B, C:

(11)

| A | B | C | |
|---|---|---|---|
| − | − | + | [F] |
| − | + | + | [G] |
| 0 | 1 | 2 | rank |

The number of terms in the hierarchy increases as we add implicational relations. Thus, the four-term hierarchy O < N < L < G results from the presence of the two implicational statements (redundancy rules) (9a–b) given earlier.

Hierarchies of this type are common elsewhere in grammar. For example, in some Bantu languages we find the following nominal hierarchy defined by the accessibility of a given nominal to direct object status: 1st person > 2nd person > 3rd person human > 3rd person animal > 3rd person inanimate (Hyman, Duranti, and Morolong 1980). In principle, it would be possible to define this hierarchy in terms of a single multivalued feature whose meaning is roughly "similarity or closeness to *ego*." However, the various positions on this hierarchy do not form a continuum, but a series of discrete steps, most of which are found to play a role elsewhere in grammar: for example, the distinction between first, second and third person animate commonly plays a role in Bantu inflectional morphology. In such cases linguists do not usually assume that a single, multivalued feature or parameter is at work, but rather that the hierarchical scale is built up out of independently-needed linguistic categories linked by implicational relations.

This seems to be the appropriate way to view the sonority hierarchy. There is, moreover, considerable phonetic and perceptual rationale for the definition of the sonority scale given in (6) and (7) in terms of the major class features. "Sonority" is a composite property of speech sounds which depends on the way they are specified for each of a certain set of features. Plus-specifications for any of these features have the effect of increasing the perceptibility or salience of a sound with respect to otherwise similar sounds having a minus-specification, for example by increasing its loudness (a function of intensity), or making its formant structure more prominent. By defining the sonority scale in terms of several independent features rather than attempting to define it in terms of a single, uniform phonetic parameter, we take a significant step toward solving the problem of "defining" sonority in phonetic terms. Moreover, we are able to relate the notion "relative sonority" directly to perceptibility, since each of the acoustic attributes associated with a plus-specification for a major class feature enhances the overall perceptibility of the sounds that it characterizes. (See Stevens and Keyser 1987 for recent discussion of the acoustic correlates of distinctive features in somewhat similar terms.)

In sum, we may regard the major class features as defining the *relative sonority* of the various speech sounds in just this sense. Although the notion of relative sonority cannot be defined in terms of any single, uniform physical or perceptual property, we need not conclude that it is a fictitious or purely subjective matter, as long as we consider it a composite attribute of speech sounds, defined in terms of a set of major class features which themselves have relatively well-defined attributes.

## 17.5 The sonority cycle

Let us now consider the way sonority-based constraints are to be formulated in core phonology. I will propose a model involving two principles, which I will term the principles of *Core Syllabification* and *Feature Dispersion.* These two principles, taken together, implement the principle of the *Sonority Cycle.*

### 17.5.1 *The Core Syllabification Principle*

I will assume that there is a more or less well-defined portion of the lexical phonology characterized by certain uniform, perseverative properties. For example, in some languages the set of syllabification rules responsible for the syllabification of underlying representations reapplies to the output of each phonological and morphological operation throughout a portion of the lexical phonology; we may call these the *core syllabification rules*, after Clements and Keyser (1981, 1983). Similarly, by a principle of conservation some languages maintain a uniform phoneme inventory throughout much or all of the lexical phonology, an effect of "structure-preservation" which Kiparsky has proposed to account for in terms of *marking conditions* (Kiparsky 1985). Furthermore, in some languages, we observe constraints on segment sequences that hold both of nonderived stems and derived stems, giving rise to "conspiracy" effects that cannot be accounted for by syllabification principles alone (see Christdas 1988 for discussion of Tamil). The segmental and sequential uniformity characterizing these inner layers of the lexical phonology does not generally extend to the postlexical phonology, and does not necessarily even characterize the entire lexical phonology where violations of structure preservation (in the strict sense that precludes the introduction of novel segment types) are found in a number of languages (Clements 1987b). I will refer to the portion of the lexical phonology





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Let us consider the nature of core
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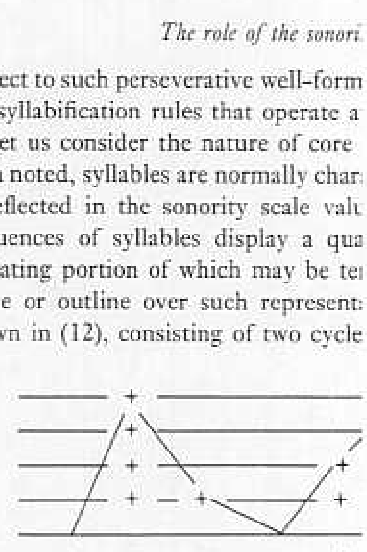


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(13) *The Core Syllabification Principle (*
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## iority cycle

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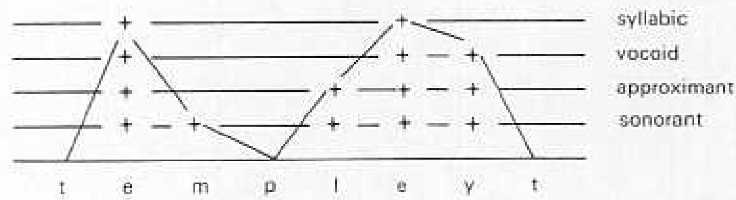
subject to such perseverative well-formedness conditions as the *core phonology*, and the syllabification rules that operate at this level the *core syllabification rules*.

Let us consider the nature of core syllabification more closely. As has widely been noted, syllables are normally characterized by a rise and fall in sonority which is reflected in the sonority scale values characterizing each of their segments. Sequences of syllables display a quasiperiodic rise and fall in sonority, each repeating portion of which may be termed a *sonority cycle*. It is possible to fit a curve or outline over such representations which reflects this rise and fall, as shown in (12), consisting of two cycles:

(12)




The number of cycles whose peaks fall on the top ([syllabic]) line of this diagram will correspond exactly to the number of syllables, except that a plateau along the top line (representing a sequence of vowels) may be parsed as a sequence of syllable peaks, as in many of the examples of (5c).

We may formulate a preliminary version of the Sonority Sequencing Principle in terms of this cyclic organization. It will be stated in terms of three steps or actions which are performed successively on segment strings to create syllables. The first of these searches for [+syllabic] segments as defined by the language in question, and introduces a syllable node over them (cf. Kahn 1980). This step presupposes that syllabic segments are already present in the representation at this point, whether created by rule or underlying (as is required in the case of languages that have unpredictable distinctions between vowels and glides or other segments differing only in syllabicity, as in French, discussed below). Further segments are syllabified by first adding segments to the left that have successively lower sonority values, and then doing the same for unsyllabified segments on the right. This yields the following principle of unmarked syllabification. I will call it the *Core Syllabification Principle* (*CSP*) for reasons that will become clear in the subsequent discussion.

(13) *The Core Syllabification Principle (CSP):*

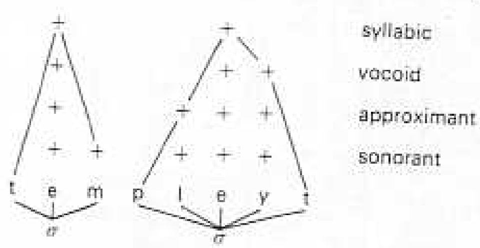
a. Associate each [+syllabic] segment to a syllable node.
b. Given P (an unsyllabified segment) preceding Q (a syllabified segment), adjoin P to the syllable containing Q iff P has a lower sonority rank than Q (iterative).
c. Given Q (a syllabified segment) followed by R (an unsyllabified segment), adjoin R to the syllable containing Q iff R has a lower sonority rank than Q (iterative).

The first iteration of (13b), which creates CV syllables, is not restricted by the sonority condition, since languages allowing syllabic consonants may permit segments of equal or higher sonority to be syllabified to their left: cf. English *yearn*, from underlying /yrn/ in which /r/ is syllabic, and similar examples in other languages (see Steriade 1982 for further observations on the special status of CV syllables). A further necessary qualification is that some languages place upper limits on the length of initial and/or final clusters created by (13), as in Turkish which does not permit syllable-initial consonant clusters in native words.[14]

The "left-precedence" or "onset-first" principle rendered explicit by the precedence given to (13b) over (13c) is widely observed in languages. Sievers (1881) had already noticed the widespread tendency toward syllabifications of the form V.CV, where C is a single consonant or a "permissible initial cluster." This observation was generalized by later linguists as the Maximal Onset Principle, which states that intervocalic clusters are normally divided in such a way as to maximize syllable onsets (see Pulgram 1970; Bell 1977; Selkirk 1982, and others). This principle applies as a strong cross-linguistic tendency just as long as the result is consistent with the CSP and with any additional language-particular restrictions on syllable length or syllable composition.[15]

In accordance with this principle, *template* is syllabified as follows:

(14)




As a consequence of the Core Syllabification Principle, intervocalic clusters will be syllabified in such a way as to both maximize the length of syllable onsets and increase the difference in sonority between their first and last members. This follows from (13b), which due to its iterative nature will continue to adjoin consonants to the initial cluster as long as each new one added is lower in sonority than the previous one. A second consequence is that a syllable which is *nonfinal* in the domain of core syllabification will have a minimal decay in sonority, since less sonorous consonants to its right will normally have been syllabified into the following syllable by the prior application of (13b).[16] Both points are illustrated in the syllabification of *template*, above, in which the Core Syllabification Principle requires *p* to syllabify rightward rather than leftward, giving the first syllable a relatively small decay in sonority at its end and the second a relatively sharp rise at its beginning. A third consequence is that syllables which are *final* in the domain of core syllabification should tend to show a maximal decay in sonority, since they





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This principle expresses a valid cross
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do not compete for consonants with a syllable to the right. The right margins of final syllables should thus tend to resemble the "mirror image" of the initial margins of initial syllables as far as their sonority profiles are concerned.

This prediction regarding codas in final syllables, though frequently true, is not exceptionless, however. In many languages the preferred syllable type is open, and closed syllables tend to be characterized by small rather than large drops in sonority finally as well as medially. When languages allow both sonorants and obstruents in final position, the set of obstruents which can occur there is frequently smaller than the set of permissible sonorants. It seems that the universally preferred syllable type tends to resemble the simple, open CV syllable as closely as possible; and a syllable approximates this type more closely to the extent that it declines less in sonority at its end. Thus a better characterization of the sonority cycle principle is that the preferred syllable type shows a sonority profile that *rises maximally toward the peak and falls minimally towards the end*, proceeding from left to right.

This principle expresses a valid cross-linguistic tendency, but does not exclude the presence of less preferred core syllable types in given languages. For example, many languages tolerate V-initial syllables, which begin with no rise in sonority at all. However, such syllables are normally restricted to word- or morpheme-initial position: in internal position, hiatus across syllable boundaries is very commonly eliminated in the core phonology by such processes as glide formation and vowel deletion. Similarly, many languages tolerate syllable types with abrupt drops in sonority at their end, or indeed syllables that have fairly complex final clusters that do not obey sonority sequencing restrictions at all. However, such clusters are generally restricted to final position in morphologically-defined domains. For example, English has a high tolerance for syllables ending in obstruent clusters (Dewey 1923; Roberts 1965). Within roots and level 1 stems, however, they are restricted to final position; internally, the inventory of syllable finals is much more restricted, and strongly favors sonorants over obstruents (Borowsky 1986).[17] The suspension of normal sonority constraints in peripheral position in the domain of syllabification can be formally characterized in terms of the notion of extraprosodicity as governed by the Peripherality Condition (Hayes 1985; Harris 1983), but may have a deeper explanation in the observation that peripheral segments are not subject to competing syllable divisions, and thus cannot give rise to alternative syllable parsings.

Viewed in this way, the sonority cycle provides a rationale for the ordering of (13b) over (13c) in the statement of the Core Syllabification Principle. This ordering, as already noted, reinforces the tendency of syllables to show a gradual decay in sonority toward their end. We will see shortly that a more precise characterization of the notion of the sonority cycle, implemented in terms of the Dispersion Principle, allows a significant simplification of the Core Syllabification Principle.

The Core Syllabification Principle is defined within the domain of core syllabification, which is fixed on language-particular grounds. This domain is the morphologically-determined portion of a form to which the core syllabification rules apply. Within the domain, the core syllabification rules and principles apply recursively to the output of each phonological or morphological operation. Thus in German, the domain of core syllabification can be identified as the morpheme (Laeufer 1985), while in English, as just noted, it is most likely identical to the stem formed by the level 1 morphology.

As noted, the CSP operates only within the margin of freedom allowed by a particular language. Thus if a language does not allow initial clusters, an intervocalic cluster will usually be heterosyllabic, even if the second member of the cluster is higher in sonority than the first. Examples are Turkish and Klamath, whose syllable-sensitive phonologies always treat the first of two intervocalic consonants as closing the first syllable, regardless of the sonority profile of the cluster (Clements and Keyser 1983). Another type of constraint is illustrated in the Germanic languages, where it is widely observed that a short stressed vowel attracts a following consonant into its syllable (Murray and Venneman 1983; Laeufer 1985). This principle has a counterpart in the English rule of Medial Ambisyllabification (Kahn 1980), which applies without regard to the general preferences expressed by the CSP. Further, some languages systematically syllabify vowels and glides together to form diphthongs, even when the following segment is a vowel. Thus in English, the glide [y] in *biology* [bay'aləji] is syllabified with the first syllable, not with the second, as is evidenced by the failure of the first vowel to reduce to schwa by Initial Destressing. These are common ways in which language-particular rules may take precedence over the CSP. These rules themselves, it should be noted, are not arbitrary but reflect independently-observed tendencies, such as the widespread dispreference for tautosyllabic clusters, or the preference for stressed syllables to be heavy.

### 17.5.2 *The Dispersion Principle*

The Core Syllabification Principle expresses a generalization about the way sequences of segments are commonly organized into syllables. It classifies syllables into two types, those that conform to the CSP, and those that violate it by presenting sonority plateaus or sonority reversals. Most frequently, if a language has syllables that violate the CSP it also has syllables that conform to it. Accordingly we will call syllables that conform to the CSP "unmarked" syllables and those that violate it "marked" syllables.

Apart from the two-way distinction between unmarked and marked syllable types, the CSP does not have anything to say about the relative complexity of syllables. This topic is treated in this section. Our basic claim will be that syllables are simple just to the extent that they conform to the optimal syllable as defined





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the syllable [spawl] of [spa,awl], the s
[a,ap], and so forth.

The demisyllable can be defined mo

(15) A *demisyllable* is a maximal sequenc
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relative position in a demisyllable.

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by the sonority cycle. Thus, the simplest syllable is one with the maximal and most evenly-distributed rise in sonority at the beginning and the minimal drop in sonority (in the limit case, none at all) at the end. Syllables are increasingly complex to the extent that they depart from this preferred profile.

In order to characterize "degree of distance from the optimal syllable" in this sense, we will first define a measure of dispersion in sonority, and then formulate the *Dispersion Principle* in terms of it. This is the principle that will serve as the basis for ranking syllable types in terms of relative complexity. As stated here, it is defined only upon unmarked syllables, that is, those that show a steady rise in sonority from the margins to the peak; other ("marked") types of syllables must be ranked by a separate method of evaluation involving an extension of the complexity metric to be given below.

In order to state the Dispersion Principle in the most revealing form, it proves convenient to make use of the *demisyllable*, a notion drawn from the work of Fujimura and his collaborators.[18] I will begin by defining this term as it is used here. A syllable is divided into two overlapping parts in which the syllable peak belongs to both; each of these parts is termed a demisyllable. In the case of syllables beginning or ending in short vowels, one demisyllable is the short vowel itself. Thus, for example, the syllable [kran] consists of the demisyllables [kra,an], the syllable [spawl] of [spa,awl], the syllable [pa] of [pa,a], the syllable [ap] of [a,ap], and so forth.

The demisyllable can be defined more formally as follows:[19]

(15) A *demisyllable* is a maximal sequence of tautosyllabic segments of the form $C_m \ldots C_n V$ or $VC_m \ldots C_n$, where $n \geqslant m \geqslant 0$.

The idea underlying the use of the demisyllable is that the sonority profile of the first part of the syllable is independent of the sonority profile of the second part. That is, there are no dependencies holding between the two parts of the syllable as far as sonority is concerned. Thus the attribute "dispersion in sonority" is most appropriately defined over the demisyllable.

If we now restate the principle of the sonority cycle in terms of demisyllables, and consider only unmarked demisyllables, we will say that the *initial* demisyllable maximizes the contrast in sonority among its members, while the *final* demisyllable minimizes it. The contrast in sonority between any two segments in a demisyllable can be stated, as a first approximation, as an integer $d$ designating the distance in sonority rank between them. For example, given the sonority scale $O < N < L < G < V$ the distance in sonority rank between N and V is 3, regardless of their relative position in a demisyllable.

The notion "dispersion in sonority" can be stated in terms of a measure of dispersion, $D$, of the distances in sonority rank $d$ between the various pairs of segments within a demisyllable. $D$ characterizes demisyllables in terms of the extent to which the sonority distances between each pair of segments is maximized: the value for $D$ is lower to the extent that sonority distances are maximal and evenly distributed, and higher to the extent that they are less maximal or less evenly distributed. It can be defined by the following equation, which is used in physics in the computation of forces in potential fields, and is proposed by Liljencrants and Lindblom (1972) to characterize the perceptual distance between vowels in a vowel system.

(16) $$D = \sum_{i=1}^{m} 1/d_i^2$$

Here, $d$ is the distance in sonority rank between each $i$th pair of segments in the demisyllable (including all nonadjacent pairs), and $m$ is the number of pairs in the demisyllable, equal to $n(n-1)/2$, where $n$ is the number of segments. It states that D, the dispersion in sonority within a demisyllable, varies according to the sum of the inverse of the squared values of the sonority distances between the members of each pair of segments within it.

Assuming the sonority scale in (6) and (7), this gives the following values of $D$ for simple CV and VC demisyllables:

(17) OV, VO = 0·06
NV, VN = 0·11
LV, VL = 0·25
GV, VG = 1·00

For CCV and VCC demisyllables, we have the following:

(18) OLV, VLO = 0·56
ONV, VGO, OGV, VNO = 1·17
NLV, VGN, NGV, VLN = 1·36
LGV, VGL = 2·25

We observe that in terms of the sonority cycle, initial demisyllables with low values for $D$ are those that show an optimal sonority profile, i.e. a sharp and steady rise in sonority, while final demisyllables with high values for $D$ show the best profile, i.e. a gradual drop in sonority. We may accordingly state the Dispersion Principle as follows:

(19) *Dispersion Principle:*
a. The preferred initial demisyllable minimizes $D$
b. The preferred final demisyllable maximizes $D$

It can be noted in passing that other ways of defining the value of D are possible in principle. For example, it might be more appropriate to restate (16) over the sum of sonority distances for *adjacent* pairs of segments only. As it happens, this





Table 17.1 *Complexity rankings for dem* *on the sonority scale* $O < N < L < G <$

| | L |
|---|---|
| a. Two-member demisyllables: | |
| i. initial: | |
| OV | 0 |
| NV | 0 |
| LV | 0 |
| GV | 1 |
| ii. final: | |
| VO | 0 |
| VN | 0 |
| VL | 0 |
| VG | 1 |
| b. Three-member demisyllables: | |
| i. initial: | |
| OLV | 0 |
| ONV, OGV | 1 |
| NLV, NGV | 1 |
| LGV | 2 |
| ii. final: | |
| VLO | ( |
| VGO, VNO | 1 |
| VLN, VGN | 1 |
| VGL | 2 |

version of (16) gives only slightly diff always very small for nonadjacent pairs, demisyllable rankings. Other possible v of the distance between members inste to yield the desired complexity rankin

We may now define a Complexity Principle as stated in (19). This metri values of $D$, and states separate condit

(20) *Complexity Metric*: For demisyllables
a. the complexity ranking, $C$, of an i terms of $D$ increases
b. the complexity ranking, $C$, of a fir terms of $D$ decreases

In the case of initial demisyllables of a g 1 to the demisyllable with the lowest and so forth. The demisyllable OV, fo between each pair of segments is he extent that sonority distances are her to the extent that they are less be defined by the following equation, on of forces in potential fields, and is (1972) to characterize the perceptual ..

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f defining the value of D are possible e appropriate to restate (16) over the of segments only. As it happens, this



Table 17.1 *Complexity rankings for demisyllables of two and three members based on the sonority scale* $O < N < L < G < V$

| | *D* | *C* |
|---|---|---|
| a. Two-member demisyllables: | | |
| i. initial: | | |
| OV | 0·06 | 1 |
| NV | 0·11 | 2 |
| LV | 0·25 | 3 |
| GV | 1·00 | 4 |
| ii. final: | | |
| VO | 0·06 | 4 |
| VN | 0·11 | 3 |
| VL | 0·25 | 2 |
| VG | 1·00 | 1 |
| b. Three-member demisyllables: | | |
| i. initial: | | |
| OLV | 0·56 | 1 |
| ONV, OGV | 1·17 | 2 |
| NLV, NGV | 1·36 | 3 |
| LGV | 2·25 | 4 |
| ii. final: | | |
| VLO | 0·56 | 4 |
| VGO, VNO | 1·17 | 3 |
| VLN, VGN | 1·36 | 2 |
| VGL | 2·25 | 1 |

version of (16) gives only slightly different values of *D*, since the value of $d^2$ is always very small for nonadjacent pairs, and proves to yield no differences in actual demisyllable rankings. Other possible versions, involving some simple summation of the distance between members instead of the inverse of the square, prove not to yield the desired complexity rankings, and need not be discussed here.

We may now define a Complexity Metric making use of the Dispersion Principle as stated in (19). This metric defines complexity rankings in terms of values of *D*, and states separate conditions for initial and final demisyllables.

(20) *Complexity Metric*: For demisyllables of length *l*,
  a. the complexity ranking, *C*, of an initial demisyllable increases as its ranking in terms of *D* increases
  b. the complexity ranking, *C*, of a final demisyllable increases as its ranking in terms of *D* decreases

In the case of initial demisyllables of a given length, this metric will assign the rank 1 to the demisyllable with the lowest value of *D*, the rank 2 to the next highest, and so forth. The demisyllable OV, for example, has the lowest value for *D*, and

Table 17.2 *Complexity rankings for one-member demisyllables (compared to two-member demisyllables)*

| | *D* | *C* |
|---|---|---|
| a. initial: | | |
| V | undefined | 5 |
| b. final: | | |
| V | undefined | 0 |

therefore the lowest complexity rank (1); NV has the second highest value for *D*, and thus the second lowest complexity rank (2); and so forth.

Two-member demisyllables fall into four degrees of complexity, as do three-member demisyllables. Complexity rankings for two-and three-member demisyllables are shown in table 17.1. It should be noticed that *C* is not proportional to *D* itself, but rather to the *ranking* defined by *D*.

(20) does not assign a value for *C* to one-member demisyllables (V), which nevertheless vary in complexity according to whether they constitute initial or final demisyllables just as longer ones do. We will therefore extend our measure of complexity in a natural way to account for these. An initial one-member demisyllable V must be regarded as highly complex as it fails to show any rise in sonority whatsoever. It must therefore be regarded as more complex than the most complex two-member initial demisyllable GV, which shows a slight (i.e. one step) rise in sonority. Since GV has a complexity rank of 4, we will assign the initial demisyllable V a complexity rank of 5. A final one-member demisyllable V, on the other hand, must be regarded as maximally simple since it conforms exactly to the pattern of the optimal CV syllable, showing no decline in sonority at all. We will give this demisyllable the complexity rank of 0, one step lower than the next most favored final demisyllable, VG. Thus we have the additional rankings in table 17.2 which rank one-member demisyllables with respect to two-member demisyllables.

Four-member demisyllables fall into one of three complexity ranks, as shown in table 17.3. The longest demisyllables that can be evaluated by this procedure, assuming the scale $O < N < L < G < V$, are the singleton five-member sets, ONLGV and VGLNO, for which $D = 5{\cdot}03$.

The same system extends to demisyllables with syllabic consonants as peaks. Recall that all syllabic consonants have a sonority ranking of 1 more than their nonsyllabic counterparts, as was shown in (6) and (7). Thus for the case of demisyllables of length 2, for instance, we have the rankings in table 17.4.[20]

The complexity rankings in tables 17.1–17.4 define a hierarchy over demisyllables. We may now state the following implications for core phonology, which hold at the level resulting from initial syllabification, which I will call L(IS).





Table 17.3 *Complexity rankings for fo*

| | *D* |
|---|---|
| a. initial demisyllables: | |
| ONGV | 2·53 |
| OLGV, ONLV | 2·67 |
| NLGV | 3·61 |
| b. final demisyllables: | |
| VGNO | 2·53 |
| VGLO, VLNO | 2·67 |
| VGLN | 3·61 |

The implications are stated only ove
type of a demisyllable depends on (i)
and (ii), what the segment type of i
addition, the Complexity Hierarchy i
length (where V-demisyllables count
explained just above). A separate Len
different lengths. These two statemen
Hierarchies, stated in (21):

(21) a. *The Complexity Hierarchy:*
For any given type *t* and leng
complexity rank *n* implies the
$n-1$.
b. *The Length Hierarchy:*
For any given type *t*, the pres
2) implies the presence of a (

By the Length Hierarchy (21b), for e
in L(IS) implies the presence of CV
Length Hierarchy does not project
mentioned these count as represent
ranked with respect to others by (2
simpler than any VC demisyllable, ar
than any CV demisyllable, by table
demisyllables under the scope of the (
to offer a principled account of the
than CV initial demisyllables, but s
than, for example, the contrary); if
Hierarchy instead, this asymmetry in
terms of an arbitrary stipulation.

*mber demisyllables (compared to two-*

IV has the second highest value for *D*,
k (2); and so forth.
r degrees of complexity, as do three-
gs for two-and three-member demi-
be noticed that *C* is not proportional
d by *D*.
ne-member demisyllables (V), which
whether they constitute initial or final
will therefore extend our measure of
for these. An initial one-member
complex as it fails to show any rise in
garded as more complex than the most
V, which shows a slight (i.e. one step)
y rank of 4, we will assign the initial
al one-member demisyllable V, on the
simple since it conforms exactly to the
no decline in sonority at all. We will
f 0, one step lower than the next most
e the additional rankings in table 17.2
respect to two-member demisyllables.
of three complexity ranks, as shown
t can be evaluated by this procedure,
are the singleton five-member sets,
3.
es with syllabic consonants as peaks.
onority ranking of 1 more than their
(6) and (7). Thus for the case of
have the rankings in table 17.4.[20]
7.1–17.4 define a hierarchy over
ing implications for core phonology,
yllabification, which I will call L(IS).



Table 17.3 *Complexity rankings for four-member demisyllables*

| | *D* | *C* |
|---|---|---|
| a. initial demisyllables: | | |
| ONGV | 2·53 | 1 |
| OLGV, ONLV | 2·67 | 2 |
| NLGV | 3·61 | 3 |
| b. final demisyllables: | | |
| VGNO | 2·53 | 3 |
| VGLO, VLNO | 2·67 | 2 |
| VGLN | 3·61 | 1 |

The implications are stated only over demisyllables of the same *type*, where the type of a demisyllable depends on (i) whether it is an initial or final demisyllable, and (ii), what the segment type of its peak is (vowel, syllabic liquid, etc.). In addition, the Complexity Hierarchy is stated only over demisyllables of the same length (where V-demisyllables count as if they were of length 2, for the reasons explained just above). A separate Length Hierarchy is stated over demisyllables of different lengths. These two statements together form the Complexity and Length Hierarchies, stated in (21):

(21) a. *The Complexity Hierarchy:*
For any given type *t* and length *l*, the presence in L(IS) of a demisyllable of complexity rank *n* implies the presence of a demisyllable of complexity rank $n-1$.

b. *The Length Hierarchy:*
For any given type *t*, the presence in L(IS) of a demisyllable of length *l* ($l > 2$) implies the presence of a demisyllable of length $l-1$.

By the Length Hierarchy (21b), for example, the presence of a CCV demisyllable in L(IS) implies the presence of CV, and so forth for longer demisyllables. The Length Hierarchy does not project a ranking for V-demisyllables, since as just mentioned these count as representing length 2; instead, V-demisyllables are ranked with respect to others by (21a), which treats a final V-demisyllable as simpler than any VC demisyllable, and an initial V-demisyllable as more complex than any CV demisyllable, by table 17.2. Notice that it is only by placing V-demisyllables under the scope of the Complexity Hierarchy in this way that we are to offer a principled account of the fact that V-demisyllables are more complex than CV initial demisyllables, but simpler than VC final demisyllables (rather than, for example, the contrary); if we were to rank them under the Length Hierarchy instead, this asymmetry in behavior would have to be accounted for in terms of an arbitrary stipulation.

Table 17.4 *Complexity rankings for demisyllables with syllabic consonants as peaks*

| | *D* | *C* |
|---|---|---|
| a. with syllabic liquids as peaks | | |
| i. initial | | |
| OL̩ | 0·11 | 1 |
| NL̩ | 0·25 | 2 |
| LL̩ | 1·00 | 3 |
| ii. final | | |
| L̩O | 0·11 | 3 |
| L̩N | 0·25 | 2 |
| L̩L | 1·00 | 1 |
| b. with syllabic nasals as peaks | | |
| i. initial | | |
| ON̩ | 0·25 | 1 |
| NN̩ | 1·00 | 2 |
| ii. final | | |
| N̩O | 0·25 | 2 |
| N̩N | 1·00 | 1 |

These principles allow us to characterize a language as more or less complex according to the following properties of demisyllables occurring at L(IS):

(22) a. the maximal value of *n* in (21a);
b. the maximal value of *l* in (21b);
c. the presence of "marked" demisyllables (those violating the CSP).

The Complexity/Length Hierarchy (21) represents a claim about the organization of phonological systems at the level of core syllabification. It maintains that core syllabification rules do not create complex types unless they create the more simple syllable types. Surface exceptions to (21) arise as a result of segmental rules creating new cluster types and later syllabification rules applying after the level of core phonology. Both types of surface exception can be illustrated from French.

In French, we find surface syllables of several types. In the first place, we find the unmarked demisyllable types OLV (*drap* 'sheet', *vrai* 'true'), OGV (*dieu* 'god', *chouette* 'owl'), NGV (*mieux* 'best', *nuage* 'cloud'), and LGV (*rien* 'nothing', *lieu* 'place', *rouan* 'roan', *lui* 'him'), as well as full range of CV demisyllables. In the second place, we find demisyllable types such as OOV (*style* 'style', *sphère* 'sphere', *psychose* 'psychosis') and more rarely ONV, NNV (*pneu* 'tire', *mnémonique* 'mnemonic'); in addition we find a few *s*-initial CCCV demisyllables, such as *spleen* 'spleen', *strict* 'strict'. The second group can be identified as nonbasic syllable types due to the fact that they are restricted to initial





position in the syllabification domain: t
internally in morphemes and simple ste
only the first set, therefore, all of which
initially and which are accordingly goo
L(IS).

Among unmarked demisyllables of l
of CGV syllables: OGV, NGV, and L(
presence of LGV (of complexity rank
(of complexity ranks 2 and 3, respectiv
It remains to determine, however,
present in L(IS).

Glides and vowels are underlyingly
restricted to words like *abbaye* [abei] 'a
is final; we find no comparable contras
find *cahot* [kao] 'jolt' and *caillot* [ka
Surface GV syllables ordinarily derive
syllables behave as vowel-initial with r
and vowels. Thus we find *les* [lez] *amis*
'the pals', illustrating the fact that the
[z] is retained, however, before the su
that this must be a vowel at the time z
1983, 96–99 for fuller discussion). We
the level L(IS) and therefore that initi
a maximum complexity of 3 at this lev
loanwords allow initial underlying glic
*les* [le] *yods*, *les* [le] *whiskys*.)

By the principle of resolvability (G
1983: 47–8), the presence of a tautosy
occurrence of tautosyllabic AB and B
core syllable rules at L(IS), we woul
principle, since as just shown GV do
CGV syllables do not contrast with (
them from the level of initial syllabific
demisyllables by the rule of Glide For
before vowels. This rule accounts
monosyllabic roots, but for alternation
[manye] 'to handle', or *avoue* [avu] 'h
e.g. Dell 1980; Noske 1982).

This leads us to the following anal
maximal complexity for initial demis
initial exceptions in nonnative words,
for demisyllables of length 3 is 1, th

*yllables with syllabic consonants as peaks*

| D | C |
|---|---|
| 0·11 | 1 |
| 0·25 | 2 |
| 1·00 | 3 |
| 0·11 | 3 |
| 0·25 | 2 |
| 1·00 | 1 |
| 0·25 | 1 |
| 1·00 | 2 |
| 0·25 | 2 |
| 1·00 | 1 |

ze a language as more or less complex
lemisyllables occurring at L(IS):

bles (those violating the CSP).

(21) represents a claim about the
t the level of core syllabification. It
lo not create complex types unless they
rface exceptions to (21) arise as a result
r types and later syllabification rules
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several types. In the first place, we find
(*drap* 'sheet', *vrai* 'true'), OGV (*dieu*
best', *nuage* 'cloud'), and LGV (*rien*
*ui* 'him'), as well as full range of CV
d demisyllable types such as OOV (*style*
sis') and more rarely ONV, NNV (*pneu*
ldition we find a few *s*-initial CCCV
*trict* 'strict'. The second group can be
the fact that they are restricted to initial





position in the syllabification domain: thus we do not find tautosyllabic sC clusters internally in morphemes and simple stems (Lowenstamm 1981). We need consider only the first set, therefore, all of which may occur word-internally as well as word-initially and which are accordingly good candidates for core syllables at the level L(IS).

Among unmarked demisyllables of length 3, then, we find OLV and three types of CGV syllables: OGV, NGV, and LGV. Missing are ONV and NLV. Since the presence of LGV (of complexity rank 4) implies the presence of ONV and NLV (of complexity ranks 2 and 3, respectively), we have an apparent violation of (21). It remains to determine, however, whether CGV demisyllables are actually present in L(IS).

Glides and vowels are underlyingly contrastive in French, but this contrast is restricted to words like *abbaye* [abei] 'abbey', *abeille* [abey] 'bee', where the glide is final; we find no comparable contrasts in prevocalic position. For example, we find *cahot* [kao] 'jolt' and *caillot* [kayo] 'clot' but no contrastive word [kaio]. Surface GV syllables ordinarily derive from underlying VV sequences, since such syllables behave as vowel-initial with respect to rules that distinguish consonants and vowels. Thus we find *les* [lez] *amis* 'the friends' contrasting with *les* [le] *copains* 'the pals', illustrating the fact that the final [z] of *les* is deleted before consonants; [z] is retained, however, before the surface glide [y] in *les yeux* [lezyö] showing that this must be a vowel at the time z-deletion applies (see Clements and Keyser 1983, 96–99 for fuller discussion). We conclude that GV syllables do not occur at the level L(IS) and therefore that initial demisyllables of length 2 are restricted to a maximum complexity of 3 at this level. (Note, however, that a small number of loanwords allow initial underlying glides, such as *yod* 'yod', *whisky* 'whisky'; cf. *les* [le] *yods*, *les* [le] *whiskys*.)

By the principle of resolvability (Greenberg 1978: 250; Clements and Keyser 1983: 47–8), the presence of a tautosyllabic cluster ABC implies the independent occurrence of tautosyllabic AB and BC. If CGV demisyllables were created by core syllable rules at L(IS), we would have a violation of this widely-observed principle, since as just shown GV does not occur independently at this level. As CGV syllables do not contrast with CVV syllables, however, we may eliminate them from the level of initial syllabification L(IS) and derive them from the CVV demisyllables by the rule of Glide Formation, which turns high vowels into glides before vowels. This rule accounts not only for the presence of (C)GV in monosyllabic roots, but for alternations such as *manie* [mani] 'I handle' vs. *manier* [manye] 'to handle', or *avoue* [avu] 'he admits' vs. *avouer* [avwe] 'to admit' (see e.g. Dell 1980; Noske 1982).

This leads us to the following analysis of core demisyllables in French. The maximal complexity for initial demisyllables of length 2 is 3 (with a few word-initial exceptions in nonnative words, as mentioned) and the maximal complexity for demisyllables of length 3 is 1, the default value for this case. Thus initial syllabification creates only OV, NV, LV, and OLV, consistently with (21), CGV demisyllables arise through the rule of Glide Formation, which applies obligatorily in initial and postvocalic position and optionally postconsonantally. For some, but not all speakers it is also obligatory when defined entirely within a single morpheme (for such speakers *lieu* 'place' is always [lyø], never [liø]). The output of Glide Formation is fully syllabified, but respects the length constraints which continue to operate through the core phonology: thus it cannot create CCGV demisyllables, and is blocked in words like *plier* 'bend', *crier* 'cry', and *grief* 'grievance', which remain bisyllabic. Interestingly, for some speakers Glide Formation can apply in *s*-initial words like *skier* [skye] 'to ski'. We may assume that for these speakers *s*-initial clusters are created by a post-core rule syllabifying initial *s* with a following consonant; at this point the core syllable constraints are no longer operative. For other speakers, this rule belongs to the core phonology.

We see, then, that surface exceptions to (21) may not be exceptions at the level of initial syllabification, at which (21) is defined. In French, surface exceptions arise in two ways: through the creation of new sequence types by the operation of Glide Formation in the core phonology, which are resyllabified subject to the length restrictions, and through the creation of new syllable types (such as s-initial clusters) by syllabification rules applying subsequently in the derivation, perhaps in the post-core phonology. This analysis directly captures the generalization that the length condition on the output of Glide Formation is identical to the length condition holding on underlying syllables. More generally, it supports our claim that sonority constraints are most suitably defined in core phonology, rather than in surface structure (section 17.3.1).

Let us turn finally to the status of "marked" demisyllables containing violations of the sonority cycle, in the form of sonority "plateaus" or "reversals" such as OOV, NOV, or LOV. Such structures are not uncommon at the surface-phonetic level in languages, as we saw in section 17.3.1, and may arise through core or post-core syllabification processes as we have just seen in French. The essential observation here is that such sonority violations are usually restricted to the periphery of the syllabification domain, where they do not give rise to problems of syllable division. A language that exhibits LOV demisyllables word-initially, for instance, does not usually tolerate them word-internally, just as languages that permit VOO demisyllables word-finally do not usually allow them in non-final syllables.

This observation does not require any new principles, since it follows directly from the CSP. Word-initially, the CSP syllabifies a sequence like LOV as L-OV, where the L remains extrasyllabic. Some languages may then have special rules allowing this segment to be incorporated into the syllable, while others may require it to be deleted. Word-internally, however, the sequence VLOV will be syllabified VL-OV by the CSP; this will be true even if the language in question





has a rule creating LOV demisyllables wo
syllabification rules restricted to domain ed
CSP. Therefore LOV demisyllables will n
the highly unusual case in which a languag
this context, for example by carrying out

There is a straightforward way to c
demisyllables containing sonority "plateau
far been integrated into the evaluation sy
deviance of "marked" demisyllables is
"unmarked" demisyllables. Thus sonor
sonority plateaus, and the complexity of sc
to the extent of the reversal: e.g. NOV is
NOV, GOV than LOV, etc. We may as
Complexity Metric to cover these cases.

This section has proposed a formal p
complexity of demisyllables of various typ
syllables. We need not attribute such co
native speakers in any sense. Rather, the re
are properties of the representations as suc
by speakers without carrying out consci
we can detect whether billiard balls ar
without doing computations on a pocket

### 17.5.3 *The Sequential*

Certain sequencing constraints holding w
by the theory developed so far. Let us con
seems to play a role.

Greenberg (1978) observes what he term
which he formulates as follows: "every la
contains at least one cluster with a final c
(p. 268). That is, if a language allows VCC
at least one of these is of the form VCT,
obstruent. Examples given by Greenberg
final clusters *ps*, *ks* and *nks*, Latin whose
*ks*, *rs*, *ns*, and Maasai with only *rn*, *rt*, and
demisyllables: as Greenberg notes, "eve
clusters contains at least one cluster with a
region" (269). As an example he cites Chi
clusters are *st* and *sd*.

Some linguists have suggested, on the b

ınd OLV, consistently with (21), CGV
le Formation, which applies obligatorily
onally postconsonantally. For some, but
hen defined entirely within a single
is always [lyø], never [liø]). The output
t respects the length constraints which
onology: thus it cannot create CCGV
ike *plier* 'bend', *crier* 'cry', and *grief*
nterestingly, for some speakers Glide
e *skier* [skye] 'to ski'. We may assume
created by a post-core rule syllabifying
s point the core syllable constraints are
his rule belongs to the core phonology.
(21) may not be exceptions at the level
defined. In French, surface exceptions
new sequence types by the operation of
which are resyllabified subject to the
n of new syllable types (such as s-initial
subsequently in the derivation, perhaps
directly captures the generalization that
de Formation is identical to the length
More generally, it supports our claim
defined in core phonology, rather than

.ed" demisyllables containing violations
rity "plateaus" or "reversals" such as
not uncommon at the surface-phonetic
3.1, and may arise through core or post-
e just seen in French. The essential
iolations are usually restricted to the
here they do not give rise to problems
s LOV demisyllables word-initially, for
word-internally, just as languages that
lo not usually allow them in non-final

new principles, since it follows directly
llabifies a sequence like LOV as L-OV,
languages may then have special rules
d into the syllable, while others may
however, the sequence VLOV will be
be true even if the language in question



has a rule creating LOV demisyllables word-initially, under the assumption that syllabification rules restricted to domain edges apply after rules that implement the CSP. Therefore LOV demisyllables will not be created word-internally, except in the highly unusual case in which a language has a rule overriding the CSP in just this context, for example by carrying out a resyllabification.

There is a straightforward way to determine the relative complexity of demisyllables containing sonority "plateaus" and "reversals," which have not so far been integrated into the evaluation system. The basic observation is that the deviance of "marked" demisyllables is proportional to their distance from "unmarked" demisyllables. Thus sonority reversals are more complex than sonority plateaus, and the complexity of sonority reversals increases in proportion to the extent of the reversal: e.g. NOV is more complex than OOV, LOV than NOV, GOV than LOV, etc. We may assume an appropriate extension of the Complexity Metric to cover these cases.

This section has proposed a formal procedure for quantifying the relative complexity of demisyllables of various types – and hence (though derivatively) of syllables. We need not attribute such computation to the explicit knowledge of native speakers in any sense. Rather, the relationships we have sought to bring out are properties of the representations as such, and can presumably be apprehended by speakers without carrying out conscious mathematical calculations – just as we can detect whether billiard balls are evenly dispersed on a billiard table without doing computations on a pocket calculator.

### 17.5.3 *The Sequential Markedness Principle*

Certain sequencing constraints holding within syllables cannot be accounted for by the theory developed so far. Let us consider cases in which place of articulation seems to play a role.

Greenberg (1978) observes what he terms the "law of the final dental-alveolar," which he formulates as follows: "every language [in the sample] with final clusters contains at least one cluster with a final obstruent in the dental-alveolar region" (p. 268). That is, if a language allows VCC demisyllables to occur in final position, at least one of these is of the form VCT, where T represents a dental or alveolar obstruent. Examples given by Greenberg include Classical Greek, with the three final clusters *ps*, *ks* and *nks*, Latin whose final clusters all end in *s* or *t*, Balti with *ks*, *rs*, *ns*, and Maasai with only *rn*, *rt*, and *rd*. A similar implication holds of initial demisyllables: as Greenberg notes, "every language [in the sample] with initial clusters contains at least one cluster with an initial consonant in the dental-alveolar region" (269). As an example he cites Chiricahua Apache, in which the only initial clusters are *st* and *sd*.

Some linguists have suggested, on the basis of observations similar to these, that coronal segments should be assigned a special rank of their own on the sonority scale. This would allow coronals to be formally treated as different in sonority from segments formed at other places of articulation. Closer consideration shows, however, that this approach weakens the notion of sonority to an undesirable degree, and does not explain the special status of anterior coronals (dentals and alveolars) compared to posterior coronals (palato-alveolars).

One reason not to assign coronals a special place of their own on the sonority scale is that the distinction between coronal and noncoronal segments of the same major class does not correspond to the required difference in perceptibility, unlike the major class features which define the scale given in (6) and (7). For example, [s] is a more salient segment than [f] or [θ] in terms of intensity and loudness, and is thus presumably more sonorous in this view, but nevertheless occurs peripherally to [p] and [k] in initial clusters like English *spit*, *skit* and in final clusters like *lapse*, *tax* where the theory requires it to be less sonorous. Nor, in particular, does such an approach help explain why [s] and [z] frequently occur peripherally to fricatives at other places of articulation, as in English *sphere*, *Jeeves* or Dutch *school* [sxo:l], *aardigst* [...xst] 'nicest'. If we are to maintain that coronals are *less* sonorant than noncoronals on the basis of the patterning of [s], we must abandon the claim that sonority is related to increased perceptibility, which seems otherwise correct.

Moreover, it is difficult to find any general position for coronals that would give a correct general account of their exceptional freedom of occurrence. On the one hand, to handle initial clusters like *sp*, *sf*, *sk*, *sx* or final clusters like *pt*, *kt*, *ps*, *fs*, *ks*, *xs* we would have to assign the coronals a lower sonority rank than noncoronals, as we have just seen. But there are considerations arguing for just the opposite analysis. As Steriade (1982) observes, we may account for the common exclusion of the initial clusters *tl*, *dl* in languages otherwise permitting OL clusters freely by the minimal distance principle if we claim that *t*, *d* have a higher sonority rank than *p*, *b*, *k*, *g*: under this assumption, *t*, *d* are "closer" in sonority to *l* than are the noncoronal stops, and hence can be excluded by a minimal distance constraint. And as Selkirk notes (1984), we must assign coronals a higher rank than noncoronals to account for languages such as Spanish and Italian in which only sonorants and *s* may close the syllable, in order to designate this set of segments as a natural class on the sonority scale. But such inconsistency in the place of coronals argues strongly against this approach.

Furthermore, it seems that one and the same language may treat coronals inconsistently. In English, as we have seen, coronals typically pattern peripherally to noncoronals in initial and final obstruent clusters, a fact which suggests that they have a lower rank on the sonority scale. This is supported by Stuart Milliken's observation (personal communication) that in single morphemes, an obstruent may follow an oral stop only if it is a coronal, regardless of whether the





cluster is intervocalic or final: thus we h
*chapter*, *capsule*, *abdomen*, *pretzel*, *facto*
those in *rapt*, *lapse*, *ritz*, *fact*, *tax*, but n
in noncoronals like *chapter*, *ratp*, etc.[21]
sonority than noncoronals, this will follo
Law (section 17.2). On the other hand,
are higher ranking than noncoronals.
fricatives that can *precede* a noncoronal o
*lisp*, *risk* but **whifper*, *whifker*, *lifp*, *rifk*;
Contact Law and the Minimal Distance I
than the noncoronal fricatives. Moreove
languages mentioned above, according to
before *l*; as pointed out, this also follow
coronal stops are higher ranking than n

For these reasons it seems undesirabl
sonority scale to accommodate distinctio
relevant facts more closely, it seems tha
provide an explanation. The observation
clusters, anterior coronals have a fre
consonants do; they are often the only se
member of clusters. It would seem reaso
property of anterior coronals, which is
place of articulation, by most markednes
recent discussion). The complexity of an
a function both of its length and of the i
although a two-member cluster is more
less complex if it contains an anterior
consonant, all else being equal. Normal
to expect exactly the pattern of prefer
observed.

We can make this observation explicit
presumably does not need to be stated
should follow from an adequate, compl

(23) *Sequential Markedness Principle:*
For any two segments A and B and a
B, then XAY is simpler than XBY.

Thus *pt* is simpler than *pk* by virtue o
forth. This principle extends to most
Clearly, however, its scope is much bro

pecial rank of their own on the sonority
ormally treated as different in sonority
rticulation. Closer consideration shows,
e notion of sonority to an undesirable
status of anterior coronals (dentals and
(palato-alveolars).
ecial place of their own on the sonority
al and noncoronal segments of the same
quired difference in perceptibility, unlike
scale given in (6) and (7). For example,
] in terms of intensity and loudness, and
this view, but nevertheless occurs
sters like English *spit*, *skit* and in final
requires it to be less sonorous. Nor, in
xplain why [s] and [z] frequently occur
f articulation, as in English *sphere*, *Jeeves*
] 'nicest'. If we are to maintain that
als on the basis of the patterning of [s],
y is related to increased perceptibility,

eral position for coronals that would give
onal freedom of occurrence. On the one
*sk*, *sx* or final clusters like *pt*, *kt*, *ps*, *fs*,
a lower sonority rank than noncoronals,
iderations arguing for just the opposite
may account for the common exclusion
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the same language may treat coronals
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ent clusters, a fact which suggests that
ty scale. This is supported by Stuart
nication) that in single morphemes, an
it is a coronal, regardless of whether the





cluster is intervocalic or final: thus we have intervocalic clusters such as those in *chapter*, *capsule*, *abdomen*, *pretzel*, *factor*, and *pixel* beside final clusters such as those in *rapt*, *lapse*, *ritz*, *fact*, *tax*, but no words with stop-initial clusters ending in noncoronals like *chapter*, *ratp*, etc.[21] If we regard coronals as ranking lower in sonority than noncoronals, this will follow from the CSP and the Syllable Contact Law (section 17.2). On the other hand, other facts in English argue that coronals are higher ranking than noncoronals. For example, [s] and [z] are the only fricatives that can *precede* a noncoronal oral stop in a morpheme: *whisper*, *whisker*, *lisp*, *risk* but **whifper*, *whifker*, *lifp*, *rifk*; this can be explained under the Syllable Contact Law and the Minimal Distance Principle only if they are *higher* in sonority than the noncoronal fricatives. Moreover, English shares the property of many languages mentioned above, according to which *t*, *d* are excluded in initial clusters before *l*; as pointed out, this also follows from the Minimal Distance Principle if coronal stops are higher ranking than noncoronal stops.

For these reasons it seems undesirable to introduce further subdivisions of the sonority scale to accommodate distinctions in place of articulation. Examining the relevant facts more closely, it seems that another principle may be better able to provide an explanation. The observations made so far show that in initial and final clusters, anterior coronals have a freer privilege of occurrence than other consonants do; they are often the only segments able to occur as the first or second member of clusters. It would seem reasonable to relate this fact to an independent property of anterior coronals, which is that they are formed at the least marked place of articulation, by most markedness criteria (see Stevens and Keyser 1987 for recent discussion). The complexity of any sequence of segments can be considered a function both of its length and of the individual segments that compose it. Thus although a two-member cluster is more complex than a one-member cluster, it is less complex if it contains an anterior coronal than if it contains some other consonant, all else being equal. Normal markedness principles, therefore, lead us to expect exactly the pattern of preference for anterior coronals that we have observed.

We can make this observation explicit in terms of the following principle, which presumably does not need to be stated as an axiom in grammatical theory as it should follow from an adequate, completely elaborated theory of markedness:

(23) *Sequential Markedness Principle:*
For any two segments A and B and any given context X__Y, if A is simpler than B, then XAY is simpler than XBY.

Thus *pt* is simpler than *pk* by virtue of the fact that *t* is simpler than *k*, and so forth. This principle extends to most of the observations we have made above. Clearly, however, its scope is much broader. Beside explaining the preference for *sk* over *fk*, for example, it also explains the general preference for clusters containing *s* as opposed to all other coronal fricatives: *s* is the least marked fricative. This explains why initial clusters in English include *sn*, *sm* but not *fn*, *fm*, *θm*, *θn*, and only marginally *šn*, *šm*. Since voiceless fricatives are less marked than voiced fricatives, it also explains the presence of initial *fr*, *fl*, *sn* beside the absence of *vr*, *vl*, *zn*, etc. Thus we need a principle like (23) in any case. But once we have it, it accounts for the preference for dentals and alveolars without the need for further elaboration of the theory of sonority.[22]

## 17.6 Theoretical results

Let us consider some of the general results and cross-linguistic predictions of our approach to sonority. These are taken up under five headings: 6.1 Sonority Sequencing Restrictions; 17.6.2 the Maximal Onset Principle; 17.6.3 Minimal Distance Constraints; 17.6.4 the Syllable Contact Law; and 17.6.5 Core Syllable Typology.

### 17.6.1 *Sonority sequencing restrictions*

As has already been pointed out, the account of sonority given above is based in the first instance on cross-linguistic generalizations of the sort noted by Greenberg (1978). These generalizations strongly support the sonority scale O < N < L < G < V. I summarize Greenberg's main results in (24)–(26), below.[23] These examples consist of implicational statements of the general form, "if a language has property A, it also has property B." We can symbolize such statements by means of expressions of the form "A → B," or "A implies B." Statements of this type are often understood as providing an indication of the relative markedness of the two properties in question, the unmarked (or less marked) value appearing to the right of the arrow. I present Greenberg's results under three general headings, which subsume Greenberg's implicational statements. (These headings are my own, not Greenberg's.)

Under (24) I have grouped a number of implications supporting the proposition that the unmarked order of segment types within an initial demisyllable is ONLGV, and within a final demisyllable VGLNO. This proposition follows from the sonority scale O < N < L < G < V and from the CSP (13), which plays the important role of distinguishing between "unmarked" and "marked" demisyllable types. For example, since "marked" LOV demisyllables are not formed by the CSP, they require the complexity of an extra syllabification rule, and are furthermore ranked as several degrees more complex than "unmarked" demisyllables such as OLV created by the CSP, by the extension of the complexity metric suggested at the end of section 17.5.2. As (24) shows, Greenberg's results strongly support this proposition, in the sense that nine of his statements are entailed by it and none are inconsistent with it. (I retain Greenberg's numbering).





(24) The unmarked order of segment
(17) LOV → OLV
(18) VOL → VLO
(19) GOV → OGV; VOG → V
(24) LNV → NLV
(25) VNL, VNN, VLL → VLN
(36′) VNN → VNO

Under (25) I have grouped furt
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proposition and none contradict it.
Syllabification Principle itself: i
mentioned in these statements are
establishes no ranking among the
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(25) Segments within the initial dem
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(33) NLV → OLV
(37) ONV → OLV

The converse of this propositior
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ıce of initial *fr*, *fl*, *sn* beside the absence
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## tical results

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*ıencing restrictions*

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(24) The unmarked order of segment types in a demisyllable is ONLGV or VGLNO:
- (17) LOV → OLV
- (18) VOL → VLO
- (19) GOV → OGV; VOG → VGO
- (24) LNV → NLV
- (25) VNL, VNN, VLL → VLN
- (36') VNN → VNO

Under (25) I have grouped further statements relating to the proposition that segments within the initial demisyllable tend to be equally and maximally distributed in sonority. Two implicational statements are entailed by this proposition and none contradict it. This proposition does *not* follow from the Core Syllabification Principle itself: in particular, the three demisyllable types mentioned in these statements are equally consistent with this principle, which establishes no ranking among them. This proposition does, on the other hand, follow from the Dispersion Principle (19), as we have already seen.

(25) Segments within the initial demisyllable tend to be equally and maximally distributed in sonority:
- (33) NLV → OLV
- (37) ONV → OLV

The converse of this proposition, that segments in final demisyllables tend to be minimally or unequally distributed in sonority, is contradicted by one statement, (34), according to which VLN → VLO. How is this discrepancy to be explained? We have already observed the common operation of rules that append extrasyllabic segments to the ends of syllabification domains. Such rules commonly create highly marked clusters, as in English, German, and many of the languages surveyed by Greenberg in which initial and final obstruent clusters occur with fairly high frequency. Segments appended by these rules are often coronal obstruents, a fact which reflects the unmarked status of these segments (cf. the Sequential Markedness Principle), as well as the fact that obstruents are just those segments that will *least* often create violations of the CSP when appended to the beginning or end of a domain. Since these properties follow from our other principles, however, it is not necessary to introduce new principles to deal with them. We therefore consider the preference for VLO demisyllables over VLN demisyllables in word-final position as reflecting the operation of rules that append extra-syllabic segments, preferentially obstruents, to the ends of domains. We expect this preference not to obtain in nonfinal syllables.

Finally, in (26) I give a number of statements supporting the view that fricatives and stops should be considered equal in rank, just as is claimed by the scale O < N < L < G < V. In these statements, "S" is to be read "stop" and "F" as "fricative". The general proposition supported by Greenberg's results here is that sequences *differing* in their specification for [continuant] are preferred to sequences *agreeing* in this specification.

(26) Contrast in continuancy is favored over its absence:
  (7) SSV → FSV, SFV
  (8) VSS → VFS, VSF
  (9) FFV → FSV, SFV
  (10) VFF → VFS, VSF

This same principle may be able to account for the widely-observed preference for demisyllables of the form [trV] or [drV] over demisyllables of the form [tlV] or [dlV]. In the first of these, the consonant cluster contrasts in terms of the feature [continuant], while in the second it does not, assuming the correctness of our earlier assumption that laterals are [−continuant].

Interestingly, Greenberg's results do not support the common view that voiced obstruents outrank voiceless obstruents in sonority. The reason for this is that obstruent clusters show a strong tendency to share all laryngeal features, including voicing.

We see, then, that the principles developed here account correctly for the crosslinguistic generalizations noted by Greenberg, including certain ones (25) that did not follow from earlier versions of sonority theory. In addition, they make further predictions regarding preferred segment order that cannot be directly confirmed on the basis of Greenberg's study (which did not attempt to evaluate all possible orderings of the segment classes O, N, L, G, V), and which must be the subject of future research.

### 17.6.2 *The Maximal Onset Principle*

This approach also allows us to derive a further generalization, the Maximal Onset Principle. In section 17.5.1, the Maximal Onset Principle was stipulated as part of the statement of the Core Syllabification Principle, by giving statement (13b) precedence over (13c). We observed that this order of precedence was in accordance with the properties of the sonority cycle, but we were unable at that point to derive it from any higher-level principle.

We are now in a position to see that at least part of this principle (and indeed its most prototypical case) follows in a straightforward manner from the Dispersion Principle: VCV is preferably syllabified V-CV, not VC-V, since V is a simpler final demisyllable than VC, and CV is a simpler initial demisyllable than V (see Table 17.2). This account extends to VCCV sequences as well. For example, the preference for the syllabification V-OLV instead of VO-LV owes to the fact that V is a simpler final demisyllable than VO, as just noted. Thus V-OLV is a simpler sequence that VO-LV by virtue of the crosslinguistic preference for open syllables, formally expressed by the statement in Table 17.2(b). (Note that





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predicts that the syllabification V-CC
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Given these results, it is no longer n
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(27) Core Syllabification Principle (revise
  a. Associate each [+syllabic] segme
  b. Give P (an unsyllabified segment)
  lower in sonority rank than Q, adj

We may allow syllabification to take plac
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Davidsen-Neilsen 1974 for contrary
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### 17.6.3 *Minimal*

A further result concerns what we ma
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ue of the crosslinguistic preference for
statement in Table 17.2(b). (Note that



in the two syllabifications under comparison, OLV cannot be ranked with respect to LV since the Complexity Metric (20) does not compare demisyllables of different length.) This account extends to VCCV sequences of all types, and predicts that the syllabification V-CCV will be preferred to VC-CV just in case CCV is an admissible core demisyllable type in the language in question.

Given these results, it is no longer necessary to give (13b) explicit precedence over (13c). The CSP can be restated as in (27):

(27) Core Syllabification Principle (revised):
a. Associate each [+syllabic] segment to a syllable node
b. Give P (an unsyllabified segment) adjacent to Q (a syllabified segment), if P is lower in sonority rank than Q, adjoin it to the syllable containing Q (iterative).

We may allow syllabification to take place simultaneously rather than directionally, with the Complexity Metric deciding between otherwise well-formed alternatives.

Significantly, the present theory differs from standard versions of the Maximal Onset Principle in being defined in terms of the universal sonority scale rather than in terms of language-particular syllabification rules. This means that in cases of alternative syllabifications, the correct one will normally conform to the universal sonority scale. Again, evidence bearing on this claim is hard to find, but some recent studies suggest that it may be correct. Hayes (1985) finds that intervocalic sequences of [s]+oral stop in English tend to syllabify as VC-CV in spite of the fact that we find [s]+oral stop clusters word-initially (see, however, Davidsen-Neilsen 1974 for contrary results), and Lowenstamm (1981) reports similar observations for French.

### 17.6.3 *Minimal distance constraints*

A further result concerns what we may term "minimal distance constraints." It has been noticed by a number of linguists that not all syllables that are well-formed in terms of the Sonority Sequencing Principle actually constitute well-formed syllables in given languages. Some languages show a strong preference for syllables in which adjacent elements are not too close to each other in sonority rank. For example, Harris (1983) observes that in Spanish, initial clusters of the form ON and NL are systematically excluded, while those of the form OL are allowed. He suggests that this is not an arbitrary property of Spanish, but reflects a tendency for languages to prefer syllables in which adjacent elements are separated by a specifiable minimal distance on the sonority scale. As he further points out, if the sonority scale for Spanish is taken to be $O < N < L < G < V$, then we may say that Spanish requires adjacent consonants in the same syllable to be nonadjacent, i.e. to observe a minimal distance of 2, on the sonority scale.

To the extent that statements of this sort prove to be simple and uniform across languages, they can be taken as providing further confirmation for the essential correctness of sonority theory, without which these relations cannot be easily expressed. However, a number of observations suggest that this principle needs some qualification. First, minimal distance constraints only seem to apply in the initial demisyllable; they typically do not govern final demisyllables, where segments tend to be close to each other in sonority, as we have seen. Furthermore, to the extent that it has been applied to a wider set of languages, this principle turns out to require increasingly idiosyncratic, language-particular versions of the sonority hierarchy in order to be made to work (see Steriade 1982; Harris 1983; Selkirk 1984; van der Hulst 1984; and Borowsky 1986, for discussion of minimal distance constraints in a variety of languages involving several different sonority scales). While the notion that segments within the syllable should not be too similar in terms of their sonority rank undoubtedly offers valid insights into syllable structure, its formalization in terms of minimal distance constraints may not be the most satisfactory way of capturing these intuitions.

The approach given here derives the main effects of minimal distance constraints without raising these problems. To see this, let us consider an example. Spanish, as noted, requires that consonants in initial clusters observe a minimal distance of 2 on the sonority scale. In a theory formally incorporating minimal distance constraints, such statements are part of the grammar, and the minimal distance value governing syllabification in each language must correspondingly be discovered by each language learner. Under such an account, the simplest possible language would be one with no minimal distance constraints at all. But this seems incorrect: minimal distance constraints appear to be quite widely observed across languages, and seem to represent the unmarked option. If this is so, we would prefer an account in which such constraints need not be stated explicitly in the grammar, but can be derived from independent principles.

Under the present theory, such an account is possible. We may describe a language such as Spanish by saying that its initial CCV demisyllables have a maximal complexity of 1. Thus the only permitted initial demisyllables are of the form OLV (see Table 17.1). If we assume that 1 is the default value in universal grammar, this value does not have to be learned. We can account for more complex cases (those of languages which tend not to observe minimal distance constraints) by assuming that the learner abandons the default hypothesis only in the face of clear evidence to the contrary. For example, if a language allows ONV or OGV demisyllables in addition to OLV demisyllables, the value of the most complex demisyllable rises from 1 to 2, and the learner abandons the null hypothesis. This result follows as a consequence of the principles given earlier, and provides a straightforward account of the valid empirical core of the notion of "minimal distance," while accounting for the skewing between initial and final demisyllables.[24] A further result is that by stating the Dispersion Principle over demisyllables rather than over consonant clusters (as in earlier approaches), we are





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the general preference for LV demis

17.6.4 *The .*

The theory presented above not
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transsyllabically. This principle, it wil
between two consecutive syllables is
higher in sonority than the beginning
principle, Murray and Vennemann
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outranks the second in sonority. Ir
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of the principle is paraphrased in (2

(28) *The Extended Syllable Contact La*
The preference for a syllabic struc
and *b* are the sonority values of A
*a* minus *b*.

This statement extends the Syllable (
including VSC. The consequence is
possible syllable contact and *a.ta* t
principle gives us the following implic
the contact types improve as we proc

(29)

| | V | G | L | N | O |
|---|---|---|---|---|---|
| V | V.V | V.G | V.L | V.N | V.O |
| G | G.V | G.G | G.L | G.N | G.O |
| L | L.V | L.G | L.L | L.N | L.O |
| N | N.V | N.G | N.L | N.N | N.O |
| O | O.V | O.G | O.L | O.N | O.O |

In the present theory, neither th
Syllable Contact Law need be stated
the Sonority Cycle as characterized ir
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each of its component demisyllables,
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To see this, let us assign an aggre
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ewing between initial and final demi-
stating the Dispersion Principle over
clusters (as in earlier approaches), we are





able to bring the syllable peak into the domain of our statements, and account for the general preference for LV demisyllables over GV demisyllables.[25]

### 17.6.4 *The Syllable Contact Law*

The theory presented above not only derives the effects of the Sonority Sequencing Principle intrasyllabically, it also derives the Syllable Contact Law transsyllabically. This principle, it will be recalled, holds that the preferred contact between two consecutive syllables is one in which the end of the first syllable is higher in sonority than the beginning of the second. In an extended version of this principle, Murray and Vennemann (1983) propose that the optimality of two adjacent, heterosyllabic segments increases in proportion to the extent that the first outranks the second in sonority. In this view, a sequence such as *am.la*, for example, constitutes a lesser violation than a sequence such as *at.ya*. Their version of the principle is paraphrased in (28):

(28) *The Extended Syllable Contact Law* (after Murray and Vennemann 1983, 520): The preference for a syllabic structure A$B, where A and B are segments and *a* and *b* are the sonority values of A and B respectively, increases with the value of *a* minus *b*.

This statement extends the Syllable Contact Law to syllable contacts of all types, including V$C. The consequence is that sequences like *at.a* exemplify the worst possible syllable contact and *a.ta* the best. This fully general version of the principle gives us the following implicational ranking of syllable contacts, in which the contact types improve as we proceed upward and rightward across the table:

(29)

| | V | G | L | N | O |
|---|---|---|---|---|---|
| V | V.V | V.G | V.L | V.N | V.O |
| G | G.V | G.G | G.L | G.N | G.O |
| L | L.V | L.G | L.L | L.N | L.O |
| N | N.V | N.G | N.L | N.N | N.O |
| O | O.V | O.G | O.L | O.N | O.O |

In the present theory, neither the Syllable Contact Law nor the Extended Syllable Contact Law need be stated separately, but follow from the principle of the Sonority Cycle as characterized in the earlier discussion. Suppose we view the complexity of any given syllable contact as a linear function of the complexity of each of its component demisyllables, taken individually. The ranking in (29) then follows straightforwardly from the complexity metric for individual demisyllables proposed in tables 17.1–17.4.

To see this, let us assign an aggregate complexity score to each of the contact types in (29) calculated as a sum of the complexity values of each of the demisyllables that constitute it. We need consider only sequences in which neither demisyllable has more than two members, since this is the prototypical case. Thus the contact N.G (representing the demisyllable sequence VN.GV) is assigned a score of 7, since the first demisyllable has a complexity value *C* of 3 and the second a complexity value *C* of 4 (see table 17.1). Proceeding in this way, we may construct a matrix from the table given in (29) by entering the appropriate scores for each contact type. We see that the optimality of a given contact type is a simple function of its aggregate complexity:

(30)

| | V | G | L | N | O |
|---|---|---|---|---|---|
| V | 5 | 4 | 3 | 2 | 1 |
| G | 6 | 5 | 4 | 3 | 2 |
| L | 7 | 6 | 5 | 4 | 3 |
| N | 8 | 7 | 6 | 5 | 4 |
| O | 9 | 8 | 7 | 6 | 5 |

### 17.6.5 *Core syllable typology*

In Clements and Keyser (1983), it was pointed out that the inventory of core syllable types is subject to certain widely observed constraints. The following types of core syllable inventories are commonly found across languages (where each C and V can represent a potential cluster):

(31) Type I: CV
Type II: CV, V
Type III: CV, CVC
Type IV: CV, V, CVC, VC

On the other hand, other logically possible types of core syllable inventories are rare or lacking:

(32) a. V, VC
b. CVC, VC
c. CV, V, VC
d. CV, CVC, VC
e. CV, V, CVC
f. CV, VC
g. V, CVC
h. V, VC, CVC

Thus we find many languages whose core syllable types fall into the set of categories in (31), but few or none whose core syllable types correspond to those in (32). Clements and Keyser point out that the attested sets in (31) are characterized by two logical implications: a closed syllable type implies an open syllable type, and a vowel-initial syllable type implies a consonant-initial type. The CV syllable type is universal, as it is implied by all the others.

These relations follow from the principles of markedness presented above. By the Complexity Hierarchy stated in (21a), closed syllables imply open syllables because final VC demisyllables imply final V demisyllables; and similarly, V-initial syllables imply C-initial syllables because V-initial demisyllables imply CV-initial





demisyllables. Skewed inventories s
that core syllabification rules are de
presence of a CV initial demisylla
phonology is sufficient to determin

## 17.7 R

This section examines two residua
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### 17.7.1 *The spec*

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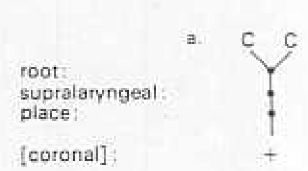


Intuitively, what makes these seque
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demisyllables. Skewed inventories such as the one in (32c) are excluded by the fact that core syllabification rules are defined on demisyllables, not syllables: thus the presence of a CV initial demisyllable and a VC final demisyllable in the core phonology is sufficient to determine the presence of a CVC core syllable type.

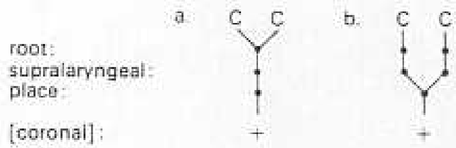
## 17.7 Residual problems

This section examines two residual problems: the treatment of geminates and other linked sequences, and the place of the major class features in the feature hierarchy.

### 17.7.1 *The special status of linked sequences*

We have said nothing as yet about a significant set of exceptions to the principles of syllable contact discussed in section 6.4. Many languages allow just a small set of intervocalic consonant clusters, typically including geminates and homorganic NC (nasal + consonant) clusters. Indeed, some languages, including Japanese, Southern Paiute, and Luganda, allow only these. As Prince points out (1984: 242–243), the generalization seems to be that languages otherwise eschewing heterosyllabic consonant clusters may allow them just in case they involve *linked sequences*: sequences sharing a single set of features. More precisely, what seems to be required is that the adjacent consonants share the place of articulation node. This is exactly what geminates and homorganic NC clusters have in common, as is shown by the following, simplified diagrams of the sequences [tt] and [nt], respectively (for this notation see Clements 1985):

(33)




Intuitively, what makes these sequences simple is the fact that they involve only a single specification for place of articulation; indeed there is some evidence that the NC clusters may be gesturally equivalent to a single consonant at the same place of articulation in some languages (see Browman and Goldstein 1986 for English and Chaga, but cf. Fujimura and Lovins 1978, note 43 for contrary results for English). We conclude from these observations that intersyllabic articulations involving a single place specification are simpler than those involving two (or more) place specifications. This principle must clearly take precedence over the sonority principles stated earlier. (On the other hand, sonority considerations may help to explain the fact that the C in NC clusters is almost always an obstruent.)

Why are geminates heterosyllabic instead of tautosyllabic? In other words, why is a word like *totta* universally syllabified *tot-ta* rather than *to-tta*? The answer to this lies in the CSP. As it scans the skeletal tier, and CSP syllabifies leftward as far as possible, first adjoining the second half of the geminate with the final vowel. It cannot syllabify the first half of the geminate with that vowel, since both skeletal C-elements dominate a single segment and thus have the same sonority rank. Consequently the first half of the geminate syllabifies with the preceding vowel. That it syllabifies into the preceding demisyllable at all, rather than e.g. being deleted due to its low sonority rank, reflects a general principle, overriding sonority considerations, to the effect that linked material is syllabified whenever possible (Christdas 1988).[26]

### 17.7.2 *The status of the major class features in the feature hierarchy*

A further question concerns the status of the major class features in the feature hierarchy. In the view presented in Clements (1985), major class features are placed under the domination of the supralaryngeal node. By assigning the major class features to the supralaryngeal node rather than to the root node, we predict that laryngeal "glides" – segments which have only laryngeal specifications – 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, avoiding positions in syllable structure that are available to true glides, and patterning now with obstruents, now with sonorants in a way often better explained by their historical origin in any given language than by their inherent phonological properties.

In assigning these features to separate tiers, however, we predict that they should be able to engage in assimilatory spreading. As pointed out independently by Schein and Steriade (1986) and Bruce Hayes (personal communication), the support for this prediction is at present quite thin. An alternative view is that they have the status of "annotations" on the supralaryngeal class node, in the sense that they are features characterizing this node, but which are not arrayed on separate tiers. This assumption would entail that major class features spread if and only if the supralaryngeal node spreads.[27]

## 17.8 General discussion

Let us review the answers we have proposed to some of the questions raised at the outset of this study:

1. *How is sonority defined in phonological theory? Is it a primitive, or is it defined in terms of other, more basic features?* We have proposed that sonority is not a primitive phonological feature, but a derived phonological property of representations definable in terms of the categories [syllabic, vocoid, approximant, sonorant].





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*y? Is it a primitive, or is it defined in* ive proposed that sonority is not a derived phonological property of the categories [syllabic, vocoid,



2. *What are its phonetic properties?* We have suggested that the phonetic correlates of sonority are just those of the major class features which define it, which share a "family resemblance" in the sense that all of them contribute to the overall perceptibility of the classes of sounds they characterize.
3. *At what linguistic level do sonority sequencing constraints hold?* We have proposed that the constraints are primarily defined in core phonology (more specifically, at the level of initial syllabification L(IS)), where syllabification obeys the Complexity/Length Hierarchy. Later rules, especially those applying at the periphery of the syllabification domain, may introduce new, more complex syllable types which create surface exceptions to the sequencing constraints.
4. *Over what units are sonority constraints defined?* It has been shown that sonority constraints are defined over demisyllables, rather than over syllables or other subsyllabic units. The demisyllable is necessary and sufficient to the statement of sonority constraints.
5. *Can languages vary in their choice of sonority scales?* We have argued that a single sonority scale, that given in (6)–(7) or a simple variant of it, characterizes sonority in all languages. Apparent language-particular variation may reflect the effect of the Sequential Markedness Principle, which holds that if only a subset of a particular class is allowed in some position, it will be the least marked subset.
6. *Can syllable types be ranked along a scale of complexity?* It has been argued that demisyllables (and derivatively, syllables) can be ranked along a scale of complexity according to the principle of the Sonority Cycle, which holds that the preferred syllable shows a sharp rise in sonority followed by a gradual fall. This principle is supported by the range of evidence discussed in section 17.6.

This approach is further supported by the simplification it allows in the description of particular languages. The core syllable inventory of a given language is largely determined by a small number of variables:

(34)
- i. the domain of core syllabification (nonderived stem, derived stem at level *n*, word, etc.);
- ii. type of permitted syllable peaks (V, L, N, ...);
- iii. maximum length of each demisyllable type;
- iv. maximum degree of complexity of each type of demisyllable (predicts the presence of all the less complex demisyllables of that type).

In addition, languages may have core syllabification rules defining well-formed "marked" demisyllable types; filters specifying systematic gaps in the set of well-formed demisyllables; and perhaps rules defining the occurrence of permissible extrasyllabic elements ("appendices", "affixes") in domain-peripheral position. It is likely, however, that such rules play a less important role in core syllabification than has previously been thought.

These results have consequences for questions regarding the formalization of syllable representation. There are many current views concerning the nature of subsyllabic constituency, and the nature of the evidence supporting one or another of these views is not always as clear or straightforward as we might like.

In contrast to some previous studies of sonority-based distributional constraints, the present theory claims that sonority contours are evaluated over the domain of the demisyllable, rather than that of the onset and rhyme. Indeed, the results summarized in this paper can be obtained *only* if we take the demisyllable as the domain of sonority constraints, since most of them make crucial reference to CV subsequences. For example, the Maximal Onset Principle requires that VCV be syllabified preferentially as V-CV rather than as VC-V, since V is a simpler final demisyllable than VC and CV is a simpler initial demisyllable than V (for any value of C). Second, we must take the initial demisyllable (rather than the onset cluster) as the basis of sonority if we are to express the preference rankings for different types of CV demisyllables stated in tables 17.1 (a)/17.2 (a) and for the different types of CCV demisyllables stated in table 17.1 (b), and hence express preferences for initial demisyllables with full generality. Third, our ability to derive prototypical cases of the Syllable Contact Law requires that sonority constraints be stated on the initial demisyllable rather than the onset cluster, since the calculation of aggregate complexity scores of VC-CV contact types depends crucially on the complexity rankings of the component VC and CV demisyllables. Finally, the theory's prediction of the implications of Core Syllable Typology also makes crucial reference to the initial demisyllable, since these implications follow from the relative complexity of CV, V, VC demisyllables.

A further claim of this theory is that sonority-based dependencies should not hold between different demisyllables. Thus (without further qualification of the theory) we would not anticipate finding sonority-based dependencies holding between initial and final demisyllables, such that an initial demisyllable having a sonority profile of type A fails to combine with a final demisyllable whose sonority profile is of type B. Nor should we expect to find sonority-based dependencies holding across syllable boundaries. These predictions are correct, as far as I know. Thus, for example, we have found that apparent "syllable contact" dependencies are derivable from an independently-motivated metric needed to express the relative complexity of individual demisyllables, and require no separate statement.[28]

## 17.9 Conclusion

The notion of the Sonority Cycle as developed above provides us with a basis for explaining the striking and significant regularities in syllable structure that we find across languages, and for integrating these observations into a formal theory of syllable representation, allowing us to capture many generalizations that have up to now been inadequately understood or explained.

Our results suggest that a significant cross-linguistic regularity of phonological





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I would like to thank Harry van de
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structure (the Sonority Cycle) may be most clearly revealed at a level of representation considerably removed from surface representation (or acoustic reality), but that this principle has a regular expression at the phonetic level through the mediation of the major class features which provide its vocabulary. Such a conclusion should not be surprising in view of the fact that what is perceptually real for native speakers may differ in significant ways from the speech signal itself; indeed this has been the lesson of phonological studies since the emergence of the modern concept of the phoneme in the work of Sapir, Trubetzkoy, Jakobson and others in the early 1930s. This result by no means implies a divorce between linguistics and phonetics, but rather takes us a step further toward solving the long-standing enigma of how abstract linguistic form is communicated through the medium of the speech waveform: significant patterning relations may be encoded at a certain degree of abstraction from the physical data, but must have a regular manifestation in the speech signal if they are to be successfully conveyed from speaker to hearer.

### *Notes*

I would like to thank Harry van der Hulst, John McCarthy, Stuart Milliken, Donca Steriade, and participants in a seminar on syllable phonology given on three occasions during 1985–1986 at Cornell University, the University of Washington, and the Summer Linguistics Institute at the University of Salzburg, for their valuable critical reactions to various presentations of the ideas in this paper. I am further grateful to Annie Rialland for discussion of the French data, and to Mary Beckman, Osamu Fujimura, and John Kingston for their written commentary on earlier drafts. All of these have contributed in some way to improvements in style and substance, although they do not necessarily agree with its conclusions. Earlier versions of this paper were presented at Yale University in November, 1985, at the Annual Meeting of the Linguistic Society of America in Seattle, Washington, in December, 1985 and at the Workshop on Features, Wassenaar, The Netherlands in June, 1986.

1 Cross-linguistic generalizations such as these, at varying degrees of abstraction from the primary data, provide the *explicanda* of theory construction in linguistics, and form the basis of the hypotheses and models that eventually come to constitute a formal linguistic theory, i.e. a theory of possible grammars and optimal grammars.

2 Sievers distinguished between the *Drucksilbe*, conceived of as an articulatory-defined syllable produced with a single independent expiratory pulse, and the *Schallsilbe*, an auditorily-defined syllable determined by the relative audibility or sonority (*Schallfülle*) of its members. These two criteria do not always coincide, as is evidenced by the German (or English) word *Hammer* which constitutes one *Drucksilbe* but two *Schallsilben*. Of these, the *Schallsilbe* is most relevant to sonority theory. See Bloomfield (1914) for a brief summary of Sievers' ideas, in which the two syllable types are termed "natural syllable" and "stress syllable."

3 Jespersen's scale differed from Sievers' in ranking all voiceless sounds before all voiced, in not attributing a separate rank to voiceless stops and fricatives, and in assigning nasals and laterals the same rank.

4 The version of the Sonority Sequencing Principle given here follows Sievers rather than Jespersen, as this is the version that is most widely followed today, cf. e.g. Kiparsky

(1979) and Lowenstamm (1981). Jespersen allowed elements of equal sonority to be adjacent within the syllable. His reluctance to adopt the more restrictive version may have been motivated by the common occurrence of initial clusters like *st* and final clusters like *ts*, which constitute anomalies under Sievers' formulation, but not under Jespersen's where *s* and *t* are of equal rank and may thus occur adjacent to each other.

5 See Pike (1942: 137–148) for a presentation of this notion, as well as Catford (1977) for more recent discussion.

6 There has been relatively little critical discussion of the notion of sonority in the recent literature; a notable exception is Bell and Saka (1983).

7 Early proponents of the theory, such as Sievers and Jespersen, did not distinguish between underlying and surface representation, and consequently assumed a surface-oriented version of the principle. Discussion in the context of generative phonology has generally recognized that the SSP interacts with other rules and principles which may give rise to surface-level exceptions. For example, Kiparsky (1979, 1981) notes that the SSP may be overridden by language-particular rules, while Fujimura and Lovins (1979) allow exceptions within syllable "affixes" that lie outside the "core."

8 This statement must be qualified by the observation that the identity of the sonority scale varies in detail from one linguist to another. What is a sonority reversal for one writer may be a sonority plateau for another, and what is a sonority plateau for one may constitute an ascending or descending ramp for another. This qualification extends to the further discussion below. Note also that the cases in (5a) represent violations of Sievers' version of the Sonority Sequencing Principle as given in (2), but not of Jespersen's, which tolerates clusters of equal sonority within the syllable.

9 Data sources for the less familiar languages are as follows: Mohawk (Michelson 1988), Cambodian (Huffman 1972), Marshallese (Bender 1976), Ewe (author's field notes, standard dictionaries), Pashto (Bell and Saka 1983), Klamath (Barker 1963), Ladakhi (Koshal 1979), Kota (Emenau 1944), Abaza (Allen 1956), Tocharian A (Coppieters 1975; J. Jasanoff, p.c.), Yatée Zapotec (Jaeger and Van Valin 1982), Turkish (Clements and Keyser 1983), Berber (Dell and Elmedlaoui 1985), Luganda (Tucker 1962), Bella Coola (Nater 1984).

10 A few representative references follow: Allen (1956) (Abaza), Dell and Elmedlaoui (1985) (Berber), Huffman (1972) (Cambodian), Nater (1984) (Bella Coola). See also Bell and Saka (1983) for a detailed examination of Pashto. (Notice that while Dell and Elmedlaoui argue that Berber largely conforms to sonority sequencing restrictions, they also recognize language-particular configurations in which these requirements are suspended.)

11 Heffner (1950: 74) states that "sonority may be equated more or less correctly with acoustic energy and its quantities determined accurately by electronic means," citing Fletcher (1929) in support. It is true that Fletcher's methods of measuring the "phonetic power" of segments give us a ranking grossly similar to familiar sonority scales, with vowels at one end and obstruents at the other. But Fletcher's results do not support the finer distinctions usually thought to be required for linguistic purposes. Thus by one of his measures (the "threshold" method), the nonanterior sibilants represented by orthographic *ch*, *sh* ranked higher in power (roughly equivalent to sonority) than nasals and all other obstruents, and the voiceless stop [k] ranked higher than fricatives or voiced stops. Moreover, Fletcher observed a high degree of interspeaker variation, suggesting that crucial details of such phonetic measures might vary substantially from speaker to speaker.

12 This definition, which follows Catford (1977: 119–127), includes voiceless sonorants,





which are normally produced with audit
consider all vowels to be approximants. Th
is not well established, and requires furthe
first introduced in Ladefoged (1964),
continuant."

13 Bell notes: "among the languages with c
vowel reduction; of those with syllabic liq
vowel reduction. The formation of syllabi
nonreduced vowel syncope is the process
vowel syncope" (171).

14 The CSP differs from a similar algorithn
(1980) in being universal rather than langu
of language-particular initial and final clus
universal sonority scale. In this view
syllabification are attributed to further par
constraints of the sort just mentioned, or
apply independently of sonority restrictio

15 Versions of the Maximal Onset Principle w
grammarians (Varma 1929; Allen 1951). It
in Indo-European, however; see Hermann
and Lejeune (1972) for relevant discussio

16 This assumes either simultaneous or right-
rules. As we will see below, our final state
(27) will be consistent with both of these

17 This skewing may explain the asymmetrie
Reilly (1986).

18 The term *demisyllable* as used here is inspi
it in significant respects. Fujimura has used
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1977), and has characterized it as follows:

> We have tentatively decided on an operat
> producing initial and final demisyllables
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In this usage, the demisyllable is an aco
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syllable core (Fujimura 1981: 79). In
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19 I assume that in languages without dipht
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en 1956), Tocharian A (Coppieters
Van Valin 1982), Turkish (Clements
985), Luganda (Tucker 1962), Bella

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the voiceless stop [k] ranked higher
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–127), includes voiceless sonorants,



which are normally produced with audible turbulence. Unlike Catford, however, I consider all vowels to be approximants. The sonority ranking of voiceless approximants is not well established, and requires further examination. The term "approximant" was first introduced in Ladefoged (1964), and replaces the older term "frictionless continuant."

13 Bell notes: "among the languages with only syllabic nasals, very few are subject to vowel reduction; of those with syllabic liquids, all but a handful do have some form of vowel reduction. The formation of syllabic liquids may be strongly disfavored where nonreduced vowel syncope is the process of origin, but not disfavored under reduced-vowel syncope" (171).

14 The CSP differs from a similar algorithm given for English syllabification by Kahn (1980) in being universal rather than language-particular. It does not syllabify in terms of language-particular initial and final clusters, as does Kahn's rule, but in terms of the universal sonority scale. In this view, language-particular differences in core syllabification are attributed to further parameters of core syllabification, such as length constraints of the sort just mentioned, or to further rules of core syllabification that apply independently of sonority restrictions, as discussed below.

15 Versions of the Maximal Onset Principle were known to the ancient Sanskrit and Greek grammarians (Varma 1929; Allen 1951). It is usually considered to have had exceptions in Indo-European, however; see Hermann (1923), Borgstrøm (1937), Schwyzer (1939), and Lejeune (1972) for relevant discussion.

16 This assumes either simultaneous or right-to-left application of the core syllabification rules. As we will see below, our final statement of the Core Syllabification Principle in (27) will be consistent with both of these modes of application.

17 This skewing may explain the asymmetries between initial and final clusters noted by Reilly (1986).

18 The term *demisyllable* as used here is inspired by Fujimura's account, but differs from it in significant respects. Fujimura has used it to designate a phonetic sequence used for the purposes of speech synthesis and automatic speech recognition (Fujimura et al. 1977), and has characterized it as follows:

> We have tentatively decided on an operational rule for "cutting" each syllable in two, producing initial and final demisyllables... The cutting rule may be stated: "Cut 60 msec after release, or if there is no release, 60 msec after the onset of the vocalic resonance." This is usually a point shortly after the beginning of the so-called steady state of the vowel, that is, after the consonant-vowel transition.

In this usage, the demisyllable is an acoustic unit. Fujimura also conceives of the demisyllable as a phonological unit, one of the two halves into which syllables "cores" are divided (Fujimura and Lovins 1977; Fujimura 1979, 1981). This unit has not previously been used in the statement of phonological rules and constraints to my knowledge, although it has been identified with the onset/rhyme distinction inside the syllable core (Fujimura 1981: 79). In my usage, for reasons to be made clear, demisyllables are not identified with onsets and rhymes; see especially section 17.8 for discussion.

19 I assume that in languages without diphthongs, long vowels are represented as VV, while in languages with (falling) diphthongs, long vowels (and falling diphthongs) are represented as VC. It follows from this and from the definition in (15) that in syllables containing long vowels $V_1V_2$, the first demisyllable ends in $V_1$ and the second begins with $V_2$, while in syllables containing VC diphthongs the first ends in V and the second

begins with the same V. In languages whose long syllable nuclei are characteristically nondiphthongal and therefore of the type VV, the distribution of long vowels tends to be equivalent to that of short vowels (see Vago 1985 for Hungarian). In contrast, in languages having diphthongs and long vowels of the type VC, such as German and English, the distribution of long vowels tends to be equivalent to that of short vowels followed by consonants (Moulton 1956; Selkirk 1982: 351).

20 Notice further that by the complexity metric (20a), OL̩ ($D = 0{\cdot}11$) is ranked as more complex than OV ($D = 0{\cdot}06$), ON̩ ($D = 0{\cdot}25$) as more complex than OL̩, and so forth. Thus, (20) predicts that syllable peaks increase in complexity as they decrease in sonority. As noted earlier, this is not quite correct, as syllables with syllabic nasals have been more frequently reported across languages than syllables with syllabic liquids. It remains to be seen whether this unexpected reversal reflects the relative complexity of syllabic nasals and liquids, or some other factor.

21 There are no exceptions to this statement in morpheme-final position. Morpheme-internally, the only common exceptions are *napkin*, *pumpkin*, *breakfast*, *magpie*, *tadpole*, *aardvark*, *Afghanistan*, and *frankfurter*. Proper names show frequent violations but may usually be analyzed into a stem and name-forming suffix, as in *Bradford/Bedford*, *Cambridge/Sturbridge*, *Lindberg/Sandberg*, *Bradbury/Woodbury*, *Tompkins/Watkins*, *Hatfield/Westfield*.

22 A similar account of the exceptional status of coronals has been proposed by Devine and Stevens (1977) in the context of their discussion of Latin syllabification (I thank John McCarthy for calling this work to may attention). There are rarer cases of languages exhibiting a preference for *non*coronals in certain positions, for which an alternative explanation will be required. One such case involves the occurrence of clusters like *kt*, *pt*, *mn* in Attic Greek to the exclusion of clusters like *tk*, *tp*, *nm*; however, Steriade (1982: ch. 4) argues that the initial members of such clusters are extrasyllabic throughout the lexical phonology.

23 A few qualifications are in order. First, Greenberg's generalizations concerned initial and final position in the *word*, not the syllable, and therefore do not necessarily translate directly into syllable structure. We have already noted that initial and final clusters in the syllabification domain (typically, the word) often deviate somewhat from initial and final clusters in internal syllables, especially in permitting extrasyllabic sequences or "appendices." As such sequences often reflect the operation of syllabification rules that override the usual sonority constraints, we would expect Greenberg's data to be less supportive of the theory developed here than generalizations based exclusively on syllabification data. Second, Greenberg's survey was based on a study of the descriptive literature, and inherits the analytical weaknesses and inadequacies of its sources. As Greenberg notes, several arbitrary choices had to be made, particularly concerning the decision whether to regard stop-fricative sequences as clusters or affricates. Third, Greenberg's implicational universals are probably best regarded as statistical rather than categorical in nature. Several implications that were true of the sample have since proven to have exceptions in other languages: thus, Ladakhi has LOV syllables but not OLV syllables (Koshal 1979), and Yateé Zapotec has the rare GOV syllable type, as noted in section 3.1. The counterpart to this is that many statements that were not categorically true of Greenberg's sample may turn out to be significant when a wider sample of languages is considered.

24 These results do not depend on the identity of the sonority scale we choose; more complex scales recognizing a larger number of points will yield the same relationship between minimal distance and degree of complexity. For example, given the hypothetical seven-point sonority scale $O < Z < N < L < R < G < V$, the most





equally distributed three-member dem
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endpoint we increase the value for *D* ar
example, OLV has the value 0·25 for *D*, C
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25 There is a further difference between t
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of a given degree of complexity. This is b
only requires that given the presence of
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by a minimal distance constraint would

26 Homorganic NC sequences are tautosyll
allows NCV syllables both initially and
plausible to analyze the NC sequence as
that the demisyllable type is actually CV

27 See, however, Milliken (1988) for an acco
rules in other languages) in terms of the

28 In some languages, however, we find con
that the sonority rank of the onset of the s
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equally distributed three-member demisyllable will be OLV. As we successively minimize the difference between the medial member of the demisyllable and either endpoint we increase the value for $D$ and thus increase the complexity value $C$. For example, OLV has the value 0·25 for $D$, ONV has the value 0·34, and OZV has the value 1·07.

25 There is a further difference between this account and accounts making use of the notion "minimal distance". Given the sonority scale O < N < L < G < V, our account predicts that we might find languages containing only one of two demisyllables of a given degree of complexity. This is because the Complexity/Length Hierarchy (21) only requires that given the presence of demisyllables of some degree of complexity $n$, demisyllables with lower degrees of complexity must also be present. For example, we should find languages with initial demisyllables of the form OGV but not ONV (or vice-versa), both of which have a complexity rank of 2. A theory in which ONV is excluded by a minimal distance constraint would necessarily exclude OGV at the same time.

26 Homorganic NC sequences are tautosyllabic in many languages, such as Bantu which allows NCV syllables both initially and word-internally. In these cases it is often plausible to analyze the NC sequence as a single prenasalized stop (Clements 1986), so that the demisyllable type is actually CV.

27 See, however, Milliken (1988) for an account of Flap Formation in English (and similar rules in other languages) in terms of the spreading of subsets of major class features.

28 In some languages, however, we find constraints holding across *pairs* of syllables such that the sonority rank of the onset of the second syllable must be equal to or greater than the sonority rank of the onset of the first. Williamson (1978), in her discussion of such a phenomenon in Proto-Ịjọ observes that it often arises historically through processes of consonant weakening in noninitial syllables, such as intervocalic voicing or spirantization. This phenomenon does not seem to reflect sonority considerations exclusively, since the dependencies in question often involve features such as voicing and continuance and may be equally well viewed as involving assimilation to the intervocalic context. Clearly, however, this is an important potential type of exception to our statement that deserves fuller and more systematic investigation.

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