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# 49. Sonority


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## Sections



## 1 Introduction

If an interface between phonetics and phonology really exists (*pace* Ohala 1990b), then one topic having a long and controversial history in that domain is sonority. Sonority can be defined as a unique type of relative, *n*-ary (non-binary) featurelike phonological element that potentially categorizes all speech sounds into a hierarchical scale. For example, vowels are more sonorous than liquids, which are higher in sonority than nasals, with obstruents being the least sonorous of all segments. In terms of traditional phonetic systems for categorizing natural classes of sounds, then, the feature encoded by sonority most closely corresponds to the notion *manner of articulation* (see CHAPTER 13: THE STRICTURE FEATURES). In this sense, sonority is like most other features: it demarcates groups of segments that behave similarly in cross-linguistically common processes. At the same time, however, sonority is unlike most features in that it exhaustively encompasses all speech sounds simultaneously, i.e. every type of segment has some inherent incremental value for this feature. Sonority is also unique in that it has never been observed to spread (assimilate), in and of itself.

A major function of sonority is to organize (order) segments within syllables. Specifically, more sonorous sounds, such as vowels, tend to occur in the nucleus, while less sonorous sounds normally appear in the marginal (non-peak) positions – onsets and codas. This concept has engendered several chronic and frequently discussed research questions:

(1) a. What role, if any, does sonority play in Universal Grammar?

b. How many and what kinds of natural class distinctions need to be made in the sonority hierarchy?

c. Are its rankings fixed or permutable 49eversible)?

d. Which distinctions in the sonority scale, if any, are universal and which, if any, are language-particular?

e. Is sonority an abstract phonological mechanism only, or does it also have a consistent, measurable phonetic basis?

To answer (1e) briefly, the main acoustic correlate of sonority is intensity. As **Ladefoged (1975**: 219) notes, "The sonority of a sound is its loudness relative to that of other sounds with the same length, stress, and pitch." Nevertheless, although much progress has been made in addressing the issues in (1), little consensus has emerged in understanding many of them. This chapter touches on each of the questions in (1), although not necessarily in the same order or to the same degree. The goal is to summarize the debates and document the types of empirical data that have been presented in arguing for the different positions. This chapter is organized as follows: §2 reviews the cross-linguistic phonological evidence for sonority. Thus §2.1 discusses the Sonority Sequencing Principle, §2.2 Minimum Sonority Distance effects, §2.3 the Syllable Contact Law, and §2.4 the contribution of sonority to the relative weight of the rhyme. §3 describes the Sonority Dispersion Principle, while §4 presents several desirable characteristics that a complete sonority hierarchy should ideally display. Finally, §5 examines the physical basis of sonority, as demonstrated experimentally.

## 2 Phonological evidence for sonority

This section describes various phonological phenomena that demonstrate that sonority is active in many languages. The exposition summarizes works discussing the issues in more depth, such as **Parker (2002)** and **Cser (2003)**. Phonotactic constraints and morphophonemic alternations provide the most compelling evidence for establishing the divisions in the sonority hierarchy. Consequently, most of the argumentation here relies on these two factors. Several patterns are attested in enough languages to motivate the hypothesis that some notion of sonority should be considered part of Universal Grammar (UG; the innate linguistic faculty shared by all humans; **Chomsky and Halle 1968**; **Kenstowicz 1994**). How sonority is best expressed in UG is a separate topic, not discussed in detail here. In many cases, opposing points of view exist, with some linguists denying that sonority is actually involved in these phenomena. See e.g. **Ohala (1974, 1990a, 1990b)** and **Kawasaki (1982)** for arguments against appealing to sonority as an explanation for these data.

### 2.1 The Sonority Sequencing Principle

The domain in which sonority is most often invoked is the syllable, and related notions such as permissible consonant clusters in onset or coda position. This reflects the analogy that the syllable is like a wave of energy (**Sievers 1893**; **Pike 1943**). Specifically, syllables universally tend to abide by the following constraint:

(2) Every syllable exhibits exactly one peak of sonority, contained in the nucleus.

This is known as the Sonority Sequencing Principle (SSP) or the Sonority Sequencing Generalization. Key works assuming this principle as a basis for analysis include **Hooper (1976)**, **Selkirk (1984)**, **Blevins (1995)**, and, in Optimality Theory, **Cho and King (2003)** and **Zec (2007)**. **Ohala (1990a, 1990b)** and **Wright (2004)** note that a rudimentary notion of the SSP is observed in the work of **de Brosses (1765)**. For the purpose of formally encoding and testing the SSP, the most frequently cited sonority scale is the following:

(3) *Modal sonority hierarchy* (e.g. Clements 1990; Kenstowicz 1994; Smolensky 1995)

vowels > glides > liquids > nasals > obstruents

←——————————————————————→

higher in sonority — lower in sonority

In terms of sonority, the five natural classes in (3) are the easiest ones to motivate and the most useful ones to employ. Assuming the SSP and the hierarchy in (3), hypothetical syllables like [ta], [kru], [wos], and [$p^{h}$lænt] are well formed, since their sonority slope uniformly rises from the beginning of the syllable to the nuclear vowel, and falls from the nucleus to the end of the syllable. Conversely, syllables containing "sonority reversals" such as [lpa] and [odm] violate (2) and are therefore illicit in most languages.

One argument for the SSP is that cross-linguistically the inventory of [+syllabic] segments in particular languages normally forms a continuous range based on a scale like (3). Thus, the propensity for a sound to occur in nuclear position is correlated with how sonorous it is. The typology of permissible syllabic segments across languages is illustrated in **Table 49.1**, adapted from **Blevins (1995)** and **Zec (2007)**.[1] The generalization is that if a language permits syllabic segments from a lower sonority class, it also allows nuclei from all higher sonority classes. In Tachelhit even voiceless stops occur in nuclear position. However, glides are omitted here since by definition they are non-nuclear. The following example lists forms containing syllabic consonants from two of these languages, where [.] marks a syllable boundary (**Parker 2002**; **Zec 2007**; **Ridouane 2008**).[2]

| | *Vowels* | *Liquids* | *Nasals* | *Obstruents* |
|---|---|---|---|---|
| Bulgarian, Hawaiian, Kabardian, Latin, Spanish | ✓ | – | – | – |
| Lendu, Sanskrit, Slovak | ✓ | ✓ | – | – |
| English | ✓ | ✓ | ✓ | – |
| (Central) Carrier, (Imdlawn) Tachelhit (Berber) | ✓ | ✓ | ✓ | ✓ |

Table 49.1 Cross-linguistic variation in syllabic segments based on sonority

(4) a. *Slovak*

[kr̩.vi] 'blood'
[vl̩.ka] 'wolf'

b. *Tachelhit*

[tz̩.dm̩t] 'gather wood'
[tr̩.gl̩t] 'lock'
[tf̩.tk̩.ts̩tt] 'you sprained it (FEM)'

Nevertheless, while the pattern in **Table 49.1** is a strong tendency, it is not universally obeyed. For example, many languages (especially in Africa) attest syllabic nasals but not syllabic liquids: e.g. Djeebbana, Lele (Chad), and Swahili (**Blevins 2006**). Thus, factors other than sonority must also be appealed to in some cases.

Besides syllabic consonants, another reason to adopt the SSP is that it accounts for tautosyllabic consonant clusters in most languages. The following example illustrates three languages that strictly follow the SSP in onsets and codas (**Blevins 2006**):

(5) a. *Cheke Holo*
[kai.ka.fli] 'flash on and off'
[kmai.kma.ji] 'eat a varied meal (reduplicated)'
b. *Djeebbana*
[n̩.ka.la] 'fork'
[kalk.bet] 'northern black wallaroo'
c. *Spanish*
[plan] 'plan'
[tɾans.kɾi.βiɾ] 'to transcribe'

Again there are exceptions; (6) shows data from two languages in which the underlined consonant clusters apparently violate the SSP (**Blevins 2006**):

(6) a. *Leti* (Indonesia)

[pni.nu] 'fool'
[sra:t] 'main road'
[rka:.lu] 'they shout'
[rstp.le] 'they sail'

b. *Yir Yoront*

[melt] 'animal, bird'
[patl] 'clean, bald'

Counterexamples to the SSP also occur in some Indo-European languages, such as Czech, Romanian, and Russian. Extreme cases are found in Georgian, a Kartvelian language attesting the word-initial clusters /zrd/, /mkrt/, /msχv/ and mt͡svrtn (**Blevins 2006**). Such exceptions have led some researchers to conclude that analyses based on sonority are circular in nature (**Ohala 1990b**: 160). However, no studies exist in which the proportion of languages with sonority reversals is tabulated among a statistically reliable and balanced sample. Therefore, based on available data, it seems safe to conclude that a large percentage of the world's languages do conform to the SSP. Furthermore, purported counterexamples like Georgian mt͡svrtn are dubious if the onset cluster in question occurs only word-initially, but not word-internally. This is crucial since, in a given language, a consonant cluster should appear in a position other than at a word edge in order to count as a canonical syllable type. Otherwise, when a greater number of consonants show up next to a word boundary, it is debatable whether this constitutes a true syllable margin. A more principled explanation is to analyze the SSP-violating segment(s) as a degenerate syllable or an extrasyllabic appendix licensed by the prosodic word. See **Cho and King (2003)** for further discussion. Finally, some alleged SSP violations cannot withstand further scrutiny. For example, **Blevins (2006)** lists Leti [rkaːlu] in (6) above. However, **van Engelenhoven (2004)** states that word-initially before another consonant the trilled /r/, nasals, /l/ and /s/ are lengthened and "syllabic." Thus, a more accurate transcription of this word is [r̩.kaː.lu]. Since the /r/ and the /k/ are not tautosyllabic, this is not a counterexample to the SSP. Rather, it confirms it.

Cross-linguistically, the most frequent exceptions to the SSP involve initial /s/ followed by a plosive, as in the English words *spill, still*, and *skill*. **Morelli (2003)** and Goad (**CHAPTER 38**: THE REPRESENTATION OF SC CLUSTERS) focus on this phenomenon. **Table 49.2** is adapted from the latter.

| *s* + | *Spanish* | *French, Western Keres* | *Greek* | *English* | *Dutch* | *German* | *Russian* |
|---|---|---|---|---|---|---|---|
| stop | – | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| fricative | – | – | ✓ | – | ✓ | – | ✓ |
| nasal | – | – | (–) | ✓ | ✓ | ✓ | ✓ |
| lateral | – | – | – | ✓ | ✓ | ✓ | ✓ |
| rhotic | – | – | – | – | (–) | ✓ | ✓ |

Table 49.2 Typological range of languages containing sC clusters

Summarizing this table, Goad observes that the lower a consonant is in sonority, the more preferred it is after an initial /s/. She thus posits that *s* + stop > *s* + nasal > *s* + lateral > *s* + rhotic, where ">" = "is more harmonic than." This scale (minus the *s*) follows many sonority hierarchies that posit more natural class distinctions than (3), such as the maximally detailed scale in §4.

**Morelli (2003)** reaches a similar conclusion. She notes that many languages have onset cluster inventories comprising three main types: (1) stop + sonorant, (2) fricative + sonorant and (3) fricative + stop. These first two satisfy the SSP, while the third reverses it (assuming that fricatives are more sonorous than stops; see below). Illustrative languages include Haida, Hindi, Hungarian, Isthmus Zapotec, Italian, Mohave, Swedish, Telugu, Yecuatla Totonac, and Yuchi. To her knowledge, however, no language exists that is analogous to these, yet completely follows the SSP: hypothetically, (1) stop + sonorant, (2) fricative + sonorant, and, crucially, (3) stop + fricative (not counting affricates). Consequently, she posits that among onset clusters consisting of two obstruents, the unmarked type is fricative + stop, where "unmarked" = phonologically default and most common (**Kenstowicz and Kisseberth 1973**: 3; **de Lacy 2006**).

Summarizing thus far, the SSP is a strong universal tendency but has exceptions. In some cases the reversals in the sonority slope are of the largest possible degree: an onset consisting of a glide followed by a voiceless stop. To illustrate, Santa María Quiegolani Zapotec exhibits many words like the following (**Regnier 1993**):

(7) [wkìt] 'game'
[wtòːʔ] 'sell (COMPLETIVE)'
[jkǎ] 'buy (POTENTIAL)'

Nevertheless, typological generalizations can still be made. For example, most languages have more consonant cluster types and tokens obeying the SSP than violating it. Furthermore, more languages attest obstruent + liquid (OL) onset clusters, for instance, than the opposite (LO). This can be stated even more forcefully as an implicational universal: if a language allows complex onsets of the type LO, it must permit OL clusters as well, whereas the inverse is not necessarily true (**Greenberg 1978**). However, this kind of observation cannot be extended to include all possible natural class combinations. For instance, Texistepec Popoluca does not permit obstruent + nasal (ON) syllable initially, yet it does allow NO clusters: [mbak] 'my bone' (**Wichmann 2002**).[3] Consequently, absolute claims about the SSP tend to break down given enough languages. Nevertheless, one apparently exceptionless statement is the following:

(8) No language exists in which all tautosyllabic consonant clusters reverse the SSP.

Returning to the five-category sonority hierarchy in (3), many phonologists expand this by making subdivisions within three of the natural classes: vowels, liquids, and obstruents (cf. (27) in §4). For example, fricatives are often claimed to be more sonorous than stops (**Hankamer and Aissen 1974**; **Steriade 1982, 1988**; **Kager 1999**). To illustrate, in Sanskrit reduplication, when a verb base begins with a consonant cluster, the prefix retains the less sonorous of these two sounds. Thus, in (9), when a stop and a continuant are adjacent in either order, the reduplicant invariably surfaces with the stop:

(9) *Sanskrit* (from Whitney 1889)

| | | | |
|---|---|---|---|
| /pratʃ$^h$/ | → | [pa-pratʃ$^h$] | 'ask' |
| /swar/ | → | [sa-swar] | 'sound' |
| /tsar/ | → | [ta-tsar] | 'approach stealthily' |
| /st$^h$a:/ | → | [ta-st$^h$a:] | 'stand' |
| /tjadʒ/ | → | [ta-tjadʒ] | 'forsake' |
| /ʃrat$^h$/ | → | [ʃa-ʃrat$^h$] | 'slacken' |
| /druw/ | → | [du-druw] | 'run' |
| /mlutʃ/ | → | [mu-mlutʃ] | 'set' |
| /rd$^h$/ | → | [a:r-di-d$^h$am][4] | |

In (9) the obvious generalization is that the reduplicant copies the less sonorous consonant from the onset of the base, regardless of its relative position within the cluster. Otherwise, if all obstruents are equal in sonority, the analysis of this process is more complicated to express (**Benua 1997**; **Hironymous 1999**). For further data and discussion of Sanskrit reduplication, see **CHAPTER 119**: REDUPLICATION IN SANSKRIT. While the full details are complex, the pattern whereby the least sonorous segment emerges in the prefix is very regular. For a mathematical explanation of this effect, see §3.

When underlying representations juxtapose sounds violating the SSP, these are repaired in four different ways cross-linguistically: (1) vowel epenthesis, (2) deletion, (3) syllabic consonants, and (4) metathesis. First, a vowel can be inserted to rescue the unsyllabifiable consonant, a process called stray epenthesis (**Itô 1986**). This occurs in Serbo-Croatian (**Kenstowicz 1994**):

(10)

| | *masculine* | *neuter* | |
|---|---|---|---|
| a. | pust | pusto | 'empty' |
| | zelen | zeleno | 'green' |
| b. | dobar | dobro | 'good' |
| | jasan | jasno | 'clear' |
| c. | bogat | bogato | 'rich' |
| | kriʒan | kriʒano | 'cross' |

In the adjective paradigm in (10), the neuter is marked by the suffix /-o/. The masculine column displays no overt morphological marking. In (10b), [a] alternates with Ø. This vowel surfaces phonetically in the final syllable of the masculine forms, between the last two consonants, but is absent in the neuter column. The contrasting forms in (10c) contain an [a] in the second syllable in both columns. This demonstrates that the alternation in (10b) involves epenthesis of [a] in the masculine forms, not syncope of underlying /a/ in the neuter column. The underlying representations of the roots in (10b) are /dobr/ and /jasn/. These underlying representations end with a consonant cluster consisting of an obstruent followed by a sonorant. If these were syllabified directly into a complex coda, they would violate the SSP. In contrast, the root /pust/ in (10a) ends with a cluster in which sonority falls. Therefore stray epenthesis is not needed since the sequence /pust/ can be exhaustively syllabified while respecting the SSP. The sonority profile of two of these contrasting roots is displayed in the following metrical-like grids (**Jespersen 1904**; **Zec 1988**; **Clements 1990**; **Kenstowicz 1994**):

(11)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| vowel | | * | | | | | * | | |
| glide | | * | | | | | * | | |
| liquid | | * | | | | | * | | * |
| nasal | | * | | | | | * | | * |
| fricative | | * | * | | | | * | | * |
| stop | * | * | * | * | | * | * | * | * |
| | p | u | s | t | | d | o | b | r |

These grids employ the five-category sonority hierarchy in (3), supplemented by obstruents being split between fricatives and stops, motivated by the Sanskrit data in (9). As these figures show, the morpheme /pust/ in isolation (in the masculine column) contains one peak of sonority (the /u/), whereas /dobr/ contains two (the /o/ and the /r/). Consequently, the motivation for inserting a vowel in the second case ([dobar]) is to rescue the /r/, which cannot be incorporated into the same syllable as the / b/ without violating the SSP.

A second process used to fix SSP violations is the deletion of an unlicensed (unsyllabifiable) consonant, known as stray erasure (**Itô 1986**). This process is illustrated by Ancient Greek. The following data show that complex onset and coda clusters are permitted, including word-medially (**Steriade 1982**; **Kenstowicz 1994**):

(12)

| | |
|---|---|
| $\text{klep}^{\text{h}}$ | 'to steal' |
| smerd.nos | 'power, force' |
| am.blus | 'dull' |
| as.tron | 'star' |
| a.elp.tos | 'unhoped for' |
| $\text{t}^{\text{h}}$elk.tron | 'charm' |
| pemp.tos | 'sent' |

The form [$\text{t}^{\text{h}}$elk.tron] demonstrates that up to four consonants can be concatenated intervocalically, providing the SSP is respected. However, in the reduplicated form /CV-$\text{grap}^{\text{h}}$-$\text{st}^{\text{h}}$ai/ → [$\text{gegrap}^{\text{h}}\text{t}^{\text{h}}$ai] 'to have been written', the underlying /s/ at the beginning of the infinitival suffix occurs between two stops. If this word were assigned a sonority profile as in (11), the /s/ would constitute a peak of sonority. However, this /s/ is not syllabic, nor can it be incorporated into a syllable with the preceding /$\text{p}^{\text{h}}$/ or the following /$\text{t}^{\text{h}}$/ without violating the SSP. Consequently, since it is prosodically unparsable, it is elided. According to **Steriade (1982)** and **Itô (1986)**, this phenomenon is a default universal mechanism automatically applying at the end of the derivation to clean up any remaining problems (see **CHAPTER 68**: DELETION).

A third strategy for dealing with SSP violations is to simply retain the offending consonant, in which case it is automatically realized phonetically as syllabic. English illustrates this with unstressed sonorant consonants in word-final clusters: *prism, button, pickle, manner.* Another example is Chamicuro (**Parker 1989**):

(13) [w-usm-i] 'I sing' [w-usm̩-kati] 'I sang'
1SG-sing-EPENTHETIC 1SG-sing-PAST

Fourth, and most rarely, SSP violations are resolved by metathesis. The most convincing case of this to date is Western Farsi. When a final vowel is deleted by a general process of apocope, an obstruent or nasal in a potential coda cluster metathesizes with a following liquid. Otherwise (without metathesis), the final liquid would constitute a separate sonority peak, which this language does not allow (**Hock 1985**):

(14)

| | | | | |
|---|---|---|---|---|
| ʧaxra | → | ʧarx | 'wheel' | |
| suxra | → | surx | 'red' | (cf. suhr-ab 'ruddy goose') |
| vafra | → | barf | 'snow, ice' | |
| asru | → | ars | 'tear' | |
| vazra | → | gurz | 'club' | |
| *namra[5] | → | narm | 'soft' | |

**Hock (1985)** attributes this alternation to the SSP. However, from his description this is primarily a historical process, so it may no longer be synchronically active.

## 2.2 Minimum Sonority Distance

While the SSP rules out many of the prohibited syllable types in most languages, it is not the full story. For example, the three syllables [kna], [kla], and [kwa] equally satisfy the SSP. Nevertheless, although many languages permit onset clusters such as [kl] and/or [kw], syllables like [kna] are much less common. One explanation for this asymmetry is a language-specific parametric requirement that the members of a tautosyllabic consonant cluster be separated by a minimum number of ranks on the sonority scale (**Steriade 1982**; **Selkirk 1984**). For example, /k/ and /l/ are sufficiently distinct in relative sonority and may therefore be combined. However, /k/ and /n/ are too close along this scale, and this is not tolerated in many languages. Conversely, a language like Russian, which permits words like /kniga/ 'book', has a lower threshold on this parameter. This condition is captured by the following principle:

(15) *Minimal Sonority Distance* (MSD)

Given an onset composed of two segments, $C_1$ and $C_2$, if $a$ = Sonority Index of $C_1$ and $b = \text{SI}(C_2)$, then $b - a \geq x$, where $x \in \{0, 1, 2, 3\}$.

Assuming the sonority hierarchy in (3), the typology of possible languages shown in **Table 49.3** is generated (cf. **Zec 2007**). The generalization is that if a language permits clusters with a lower sonority distance, it allows clusters of all higher sonority distances as well, *ceteris paribus*. The inverse of this is not true. The reversed counterparts of these onsets, such as *LO, can be excluded by the independently motivated SSP when necessary (§2.1). The data in (16) illustrate typical consonant sequences from each of the four language types in **Table 49.3**. Naturally, not every cluster type is fully productive for all phoneme combinations in these languages. Nevertheless, enough representative examples occur to justify the general trends.

| | *Maximal inventory of permissible onset clusters* | *Languages* |
|---|---|---|
| MSD = 0 | OO, ON, OL, OG, NN, NL, NG, LL, LG, GG | Bulgarian, Leti |
| MSD = 1 | ON, OL, OG, NL, NG, LG | Chukchee |
| MSD = 2 | OL, OG, NG | Gizrra, Kurdish, Spanish |
| MSD = 3 | OG | Mono, Panobo, Japanese (?), Mandarin Chinese (?) |

Table 49.3 Minimal Sonority Distance language types

(16) a. *Leti* (van Engelenhoven 2004)
[ptu.na] 'star'
[tmu.ra] 'tin'
[kru.ki] 'crab (sp.)'
[m̩.kwo.ri] 'you (SG) lift'

b. *Chukchee* (Kämpfe and Volodin 1995)
[plətkuk] 'end, finish, conclude'
[qlikkin] 'twenty'
[tretʃejwəɣˀe] 'I will go'
[ljuɾ] 'suddenly'

c. *Gizrra* (van Bodegraven and van Bodegraven 2005)
[glɛs] 'dew'
[ta.pɾaz.də] 'on (his) fangs'
[djao] 'palm (sp.)'
[uɾ.mjao] 'tree (sp.)'

d. *Panobo* (Parker 1992)
[hwĩn.ti] 'heart'
[βwi.ni.kæ̃j̃] 'they are taking, carrying'
[pja.ka] 'nephew, niece'
[wa.ta.tjan] 'last year'

As **Table 49.3** displays, a significant implication of the MSD approach is that the ideal onset cluster consists of an obstruent plus a glide, all else being equal. Thus, if a language allows complex onsets and has glides in its phonemic inventory, it must permit stop + glide clusters. This is the only onset sequence occurring in all four language types in **Table 49.3**. An explanation for this is that these two natural classes (stops and glides) are maximally separated in terms of their relative sonority, since they occupy the extreme ends of the scale (among consonants). **Baertsch (2002)** proposes one way to capture MSD effects in Optimality Theory (OT: **Prince and Smolensky 1993**). The corresponding prediction is that some languages should exist which permit OG but no other onsets. Two such cases are Mono (Democratic Republic of the Congo; **Olson 2005**) and Panobo. Other possibilities are Japanese (**Vance 1987, 2008**) and Mandarin Chinese (**Yuan 1989**). The latter two are listed in **Table 49.3**, followed by question marks to highlight their controversial status. Also, in Hindi (**Ohala 1983**) and Koluwawa (**Guderian and Guderian 2005**), the only initial clusters are OG and NG, but not *OL. There is, however, a problem. In a sequence like [kwa], the [w] is potentially ambiguous since it allows different phonological interpretations. A priori it could pertain to a diphthongal nucleus rather than the onset: [ku͡a]. Alternatively, it might be a secondary articulation (labialization) of the preceding /k/: [kʷa]. If so, then there really is no consonant cluster, just a single complex phonemic unit. The third possibility is that [kw] simply constitutes a true onset cluster, as in Panobo. Teasing apart these different conclusions is complicated, and often the language-specific evidence is not compelling either way. Unfortunately, then, when no other canonical onset clusters (such as OL) exist in a language, the argumentation is in danger of circularity regardless of which segmentation is posited. See §3 for an alternative model that claims that the unmarked initial cluster is not OG but OL. Finally, in the MSD approach, the sonority distance between the second onset consonant and the vowel is not crucial, because phonotactic restrictions rarely obtain across onset-nucleus junctures (**Blevins 1995**).

However, see §3 for an approach in which the nature of this sequence ($C_2$ + V) does matter. See also CHAPTER 15: GLIDES for further discussion of glides, and CHAPTER 55: ONSETS for an expanded treatment of onsets.

Another sonority-based principle active in many languages is the Syllable Contact Law (SCL). Some seminal references are **Hooper (1976)**, **Murray and Vennemann (1983)**, and **Clements (1990)**. More recent treatments of the SCL as a family of OT constraints include **Davis (1998)**, **Gouskova (2004)**, and **Zec (2007)**. The following are two typical formulations of the SCL:

(17) *Syllable Contact Law*

a. A heterosyllabic juncture of two consonants *A.B* is more harmonic (ideal) the higher the sonority of *A* and the lower the sonority of *B*.

b. In any heterosyllabic sequence of two consonants *A.B*, the sonority of *A* is preferably greater than the sonority of *B*.

By (17), for example, the sequence [l.k] is inherently less marked than [k.l]. **Vennemann (1988**: 50) provides a list of sample repair strategies that languages employ to improve satisfaction of the SCL. These are summarized in **Table 49.4**, as annotated by **Davis (1998**: 183) and supplemented by Seo (CHAPTER 53: SYLLABLE CONTACT), which offers more data and discussion. Based on a survey of 31 languages with SCL effects, her results give a better idea of the range of typological generalizations and their relative robustness. For example, Kazakh tolerates a /j-l/ juncture, as in [mandaj.lar] 'foreheads', since sonority drops slightly from /j/ to /l/. Kyrgyz, nevertheless, requires a greater fall in sonority and maps /aj-lar/ to [aj.dar] 'moons' (**Davis 1998**).

| *Process* | *Illustration* | *Language* | *Example* |
|---|---|---|---|
| coda weakening | g.n → w.n | Hausa | /hagni/ → [haw.ni] 'left side' |
| onset strengthening (desonorization) | k.l → k.t | Kyrgyz | /konok-lar/ → [konok.tar] 'guest-PL' |
| | l.l → l.d | Kazakh | /kol-lar/ → [kol.dar] 'hand-PL' |
| | z.l → z.d | Kazakh | /koŋuz-lar/ → [koŋuz.dar] 'bug-PL' |
| | z.m → z.b | Kazakh | /koŋuz-ma/ → [koŋuz.ba] 'bug-INT' |
| tautosyllabification | k.l → .kl | Germanic | [tɛk-.lɪç] 'daily', [e.klɪç] 'disgusting' |
| gemination | b.r → b.br | Latin > Italian | /labɾum/ → [lab.bɾo] 'lip' |
| epenthesis | n.r → n.dr | Spanish | /beniɾ-a/ → [ben.dɾa] '(s/he) will come' |
| regressive assimilation | k.m → ŋ.m | Korean | /kuk-mul/ → [kuŋ.mul] 'broth' |
| progressive total assimilation | g.n → g.g | Pali | /lag-na/ → [lag.ga] 'attach (PAST PART)' |
| regressive total assimilation | n.l → l.l | Korean | /non-li/ → [nol.li] 'logic' |
| anaptyxis | p.r → pV.r | Ho-Chunk | /hipres/ → [hiperes] 'know' |
| metathesis | d.n → n.d | Sidamo | /gud-nonni/ → [gun.donni] 'they finished' |

Table 49.4 Alternations motivated by the Syllable Contact Law

Examining the details of SCL phenomena in particular languages allows us to establish subtle differences in sonority ranks.

For instance, Spanish attests words such as [per.la] 'pearl' and [al.re.ðe.ðor] 'around', yet the hypothetical sequence *[l.r] systematically does not occur. When such a juncture would be created, an intrusive stop appears instead. This happens when the future tense is derived by dropping the infinitival theme vowel: /saliɾ/ 'to leave' → *[sal.ɾa] → [sal.dɾa] '(s/he) will leave'. These facts motivate the following sonority hierarchy among Spanish liquids, based on the second of the two definitions in (17): flap > lateral > trill (**Bonet and Mascaró 1997**; **Parker 2008**).

Nevertheless, there are problems with the SCL too. For example, it predicts that obstruent + sonorant junctures should be "fixed" more often than sonorant + sonorant clusters, *ceteris paribus*. The opposite in fact is true (**CHAPTER 53**: SYLLABLE CONTACT). Furthermore, in Akan both /O–N/ and /N–O/ sequences result in phonetic [NN]. The latter is a mirror image of Korean nasal assimilation (**Table 49.4**), even though this makes syllable contact worse: /óń–dú/ → [óń.núˀ] 'he should arrive' (**Schachter and Fromkin 1968**).

## 2.4 Rhyme weight

It is well known that the heavier a syllable is, the more it tends to attract stress (**Hayes 1980**; **Prince 1990**). For example, open syllables are light, but closed syllables are usually bimoraic. Thus, they may be obligatorily stressed (see also **CHAPTER 57**: QUANTITY-SENSITIVITY). Also, in some languages, rhymes headed by /e/ or /o/ attract stress more than those with /i/ and /u/, indicating that mid vowels have more weight than high vowels in these systems. Furthermore, the propensity for a coda consonant to project a mora is correlated with how sonorous it is (**Zec 1988, 1995**). An adequate theory of phonology should provide a unified (non-accidental) explanation for these facts. Appealing to a scalar feature like sonority allows us to do that. Based on case studies examining the relationship between segmental quality and syllable weight effects, the following hierarchy of vowel sonority has been posited (**Kenstowicz 1997**; **de Lacy 2002, 2004, 2006, 2007a**). Specific languages may choose to exploit different subsets among these natural classes:

(18) *Relative sonority of vowels*

a > e, o > i, u > ə > ɨ

To illustrate, Kobon vowels are divided into four groups in terms of stress assignment: /a/ > /e o/ > /i u/ > /ə ɨ/. In this case the potential distinction between /ɨ/ and /ə/ is underexploited. In unaffixed Kobon words, stress predictably falls on the most sonorous nucleus within a disyllabic window at the right edge (**Davies 1980, 1981**):

| | | | |
|---|---|---|---|
| (19) | a > e | [haŋˈgaβe] | 'blood' |
| | a > i | [kʰi.ˈa] | 'tree (sp.)' |
| | a > ə | [kʰəβəˈja] | 'rat' |
| | a > ɨ | [ˈaɲɨm-ˈaɲɨm] | 'lightning' |
| | o > u | [ˈmo.u] | 'thus' |
| | o > i | [si.ˈoŋkʰ] | 'bird (sp.)' |
| | o > ɨ | [gɨˈɾo-gɨˈɾo] | 'talk (mother pig to piglet)' |
| | i > ə | [gaˈɽinəŋ] | 'bird (sp.)' |
| | i > ɨ | [ˈjimbɨɽ] | 'very' |

The generalization in (18) and (19) is that vowels which are more peripheral in the acoustic space are more sonorous than central ones. Furthermore, within these two sets, segments involving a lower jaw configuration outrank their higher counterparts (**Coetzee 2006**). At the bottom of this hierarchy, /ə/ is higher in sonority than /ɨ/. This is due to languages such as Lushootseed, in which /ə/ can be stressed (unlike English) when it is the only nucleus in a root. Stress falls on the first "full" vowel of the stem; otherwise on the first schwa (**Urbanczyk 2006**):

(20) *Stressable /ə/ in Lushootseed*

| | |
|---|---|
| [ˈʔitut] | 'sleep' |
| [dzəˈɬixʷ] | 'creek' |
| [ˈʧuqʷu-d] | 'to whittle something' |
| [ʧəˈgʷas] | 'wife' |
| [k'əˈdaju] | 'rat' |
| [ˈʤəsəd] | 'foot' |
| [ˈbəʧ] | 'fall down' |

Other languages in which sonority is crucial to stress assignment include Pichis Ashéninka (**Payne 1990**; **Hayes 1995**), Komi (**Hayes 1995**; **de Lacy 1997**), and Finnish (**Anttila 1995**; **Hayes 1995**). However, a reviewer notes that contrastive /ə/ in languages like Lushootseed may be different in quality from phonetic [ə] resulting from reduction in English and analogous languages. For example, the former is probably longer in duration than the latter. This is a valid point that must be controlled for in cross-linguistic comparisons of this sort. For Lushootseed, Urbanczyk posits a phonemic /ə/ in underlying forms. In motivating a constraint against stressed schwas she writes:

> *ə́ has the distributional hallmarks of a markedness constraint because there are languages which never stress schwa, languages which avoid stressing schwa, and languages which permit schwa, along with other vowels, to be stressed, but no language enforces the stressing of schwa in preference to other vowels. (**Urbanczyk 2006**: 210)

She then lists other Salishan languages in which this prohibition is active (2006: 211, fn. 24). See **CHAPTER 26**: SCHWA for further discussion of schwa in general.

Concerning the relative weight of coda consonants, the typological range of languages is also dependent on sonority. **Table 49.5** is adapted from **Zec (1995, 2007)**. The generalization is that if a lower-sonority class is moraic in a particular language, then all higher-sonority categories are also moraic in syllable-final position. **Zec (2007)** knows of no language in which coda liquids count as heavy but nasals do not; she considers this an accidental gap. In addition to stress attraction, other diagnostics for consonant moraicity are: (1) the ability to bear a contrastive tone (Tiv; **Zec 1995**), (2) prosodic minimality (Fijian; **Dixon 1988**), and (3) blocking of processes such as vowel reduction (Maithili; **Hayes 1995**) (see also **CHAPTER 33**: SYLLABLE-INTERNAL STRUCTURE). (21) gives sample data from the three attested language types in **Table 49.5**:

| *Natural classes contributing to syllable weight* | *Languages* |
| --- | --- |
| vowels only | Fijian, Halh Mongolian, Lardil, Yidiny |
| vowels and liquids | ? |
| vowels, liquids, and nasals | Gonja, Kwakiutl, Lithuanian, Tiv |
| vowels, liquids, nasals, and obstruents | Egyptian Arabic, English, Latin, Maithili |

Table 49.5 Inventories of moraic segments

(21) a. *Fijian* (Dixon 1988)
Stress the syllable containing the penultimate mora (closed syllables do not occur).

| | |
| --- | --- |
| ['siŋa] | 'day' |
| [$^{m}$bu'taˀo] | 'steal' |
| [$^{m}$buta'ˀoða] | 'steal-TRANS' |
| [ˀi'laa] | 'know-TRANS' |
| ['raiða] | 'see-TRANS' |
| ['lu.a] | 'vomit (VB)' |

b. *Tiv* (Zec 1995)
Only sonorant consonants occur in codas, where they bear tone.

| | |
| --- | --- |
| [báŕ] | 'salt' |
| [fá'ḿ] | 'rainy season' |
| [rùmùǹ] | 'agreed, confessed' |

c. *Egyptian (Cairene) Arabic* (Hayes 1995)
Stress the ultima if superheavy (trimoraic), otherwise the penult if heavy, otherwise the antepenult.

| | |
| --- | --- |
| [ka'tabt] | 'I wrote' |
| [hadʒ'dʒa:t] | 'pilgrimages' |
| ['be:tak] | 'your (MASC SG) house' |
| [ka'tab.ta] | 'you (MASC SG) wrote' |
| [mu'dar.ris] | 'teacher' |
| [ˀin'kasara] | 'it got broken' |
| ['kataba] | 'he wrote' |

If fricatives are more sonorous than stops (§2.1), by implication some languages should exist in which fricatives occur in coda position but stops do not. This is exemplified by Panobo. Syllable-final consonants include glides, nasals, and fricatives. However, this is complicated by the fact that the flap /ɾ/ occurs in onsets, yet not in codas. Evidence that coda consonants are moraic in Panobo is that in word-final position they attract stress. Otherwise, the default quantity-sensitive foot type, a moraic trochee, assigns stress to the penultimate syllable (**Parker 1992**):

(22) *Heavy final syllables in Panobo*

| | |
|---|---|
| ['atsa] | 'manioc' |
| [ka'noti] | 'bow (weapon)' |
| [ja'wiʃ] | 'opossum' |
| [tah'põŋ] | 'root' |
| [pih'kə̃j̃] | '(they) will eat' |

## 3 The Sonority Dispersion Principle

**Clements (1990)** proposes an approach to syllable phonotactics that is also based on sonority. In his model, syllables are divided into two parts. The initial demisyllable consists of any onset consonants (if present) plus the nucleus, and the final demisyllable contains the nucleus plus the coda, i.e. the rhyme. The term demisyllable is borrowed from **Fujimura and Lovins (1978)**. The nucleus crucially resides in both demisyllables simultaneously. For example, the word /plom/ contains the demisyllables /plo/ and /om/. The essence of the Sonority Dispersion Principle (SDP) is that initial demisyllables are preferred when their constituents are maximally and evenly dispersed in sonority; e.g. /ta/. The same tendency is inverted for final demisyllables, favoring open rhymes (those ending with a vowel). More precisely, initial demisyllables of the same length (number of segments) are more harmonic to the degree that they minimize *D* in (23) below. Conversely, final demisyllables are more harmonic to the degree that they maximize *D*, all else being equal. The formula for *D* comes from the realms of physics and geometry, where it governs the distribution of mutually repelling forces in potential fields (like electrons). Its linguistic use originates with the work of **Liljencrants and Lindblom (1972)** on perceptual distance between segments in the acoustic vowel space. **Hooper (1976)** and **Vennemann (1988**: 13–14) anticipate its application to sonority and syllable structure.

(23) *Sonority Dispersion Principle*

$$D = \sum_{i=1}^{m} \frac{1}{d_i^2}$$

where $d$ = distance between the sonority indices of each pair of segments, and $m$ = number of pairs of segments (including non-adjacent ones), where $m = n(n-1)/2$, and where $n$ = number of segments.

**Clements (1990**: 304) paraphrases (23) as follows: "D … 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" a demisyllable. *D*, then, is the reciprocal of dispersion. To illustrate the application of (23), Clements assumes a sonority scale with the five categories from (3):

(24)

| | | *sonority index* |
|---|---|---|
| vowels | (V) | 5 |
| glides | (G) | 4 |
| liquids | (L) | 3 |
| nasals | (N) | 2 |
| obstruents | (O) | 1 |

When *D* is computed for demisyllables containing exactly one or two consonants, it yields the following values (ignoring types that violate the SSP):

(25) *Sonority Dispersion demisyllable values*

| | | | | |
|---|---|---|---|---|
| a. | OV = .06 | most natural onset | b. | OLV = .56 |
| | NV = .11 | ↑ | | OGV = 1.17 |
| | LV = .25 | | | ONV = 1.17 |
| | GV = 1.00 | ↓ | | NGV = 1.36 |
| | | | | NLV = 1.36 |
| c. | VO = .06 | least natural coda | d. | VLO = .56 |
| | VN = .11 | ↑ | | VGO = 1.17 |
| | VL = .25 | | | VNO = 1.17 |
| | VG = 1.00 | | | VGN = 1.36 |
| | | ↓ | | VLN = 1.36 |
| | | most natural coda | | VGL = 2.25 |

In (25a) the SDP favors a single syllable-initial consonant that maximizes the sonority slope between the onset and the vowel. Therefore, it correctly predicts that the preferred syllable of type CV has an onset consonant as low in sonority as possible (*D* = .06). This results in the following scale of relative unmarkedness: /ta/ > /na/ > /la/ > /ja/. This is foreshadowed in the discussion of Sanskrit reduplication (§2.1). Recall that the pattern there demonstrates that fricatives can outrank stops in sonority. Therefore, not all obstruents are necessarily equal in sonority (see §4).

Summarizing thus far, a unique consequence of the formula for *D* is that in an initial demisyllable of two segments (CV), the segments should differ from each other in sonority as much as possible. This is somewhat analogous to the MSD approach for onset clusters (§2.2). However, when the initial demisyllable contains three segments (CCV), what matters (given *D*) is that the aggregate total of the sonority distances between all of these together be maximized. This is accomplished by spacing apart the segments as evenly as possible (in sonority). This results in the best evaluation for OLV in (25b), since it has the lowest obtained value (.56). This is because liquids fall precisely midway between obstruents and vowels in terms of their sonority indices in Clements's five-category scale in (24). As evidence for the SDP, Clements notes that underlyingly French permits complex demisyllables of the type OLV only. However, in surface forms, some instances of OGV also exist. This raises an important typological question: which onset cluster is universally unmarked, OL or OG? On the one hand (as noted in §2.2), the MSD principle predicts that some languages should permit OG but not *OL. This seems to be correct, but see the caveats in §2.2. On the other hand, the SDP claims that OL is preferred. One piece of evidence that could help resolve this would be an alternation mapping underlying OLV to OGV, or vice versa. Unfortunately, no such process has yet been observed. A cross-linguistic survey documenting the number of languages with one type of cluster but not the other would also be enlightening. It may be that both kinds of onsets (OG and OL) need to be optimal simultaneously, i.e. in the grammars of different languages. Rod Casali and Ken Olson (personal communication) note that apparent OG-only languages are especially common in Africa.

Finally, the SDP assigns an equal evaluation to the two demisyllable types OGV and ONV in (25b). This may be problematic, since many languages exhibit the initial sequence OG, but not *ON. For example, **Table 49.3** mentions Gizrra, Kurdish, Mono, Panobo, and Spanish. However, Clements does not claim that demi-syllables of the same rank necessarily co-occur in any language containing one of them. At the same time, no languages appear to allow ONV but not *OGV. If this is a systematic gap, it is troubling for the predictions of the SDP.

## 4 The complete sonority hierarchy

Perhaps no issue in phonological theory has led to more competing proposals than the internal structure of the sonority hierarchy, i.e. the numbers and types of natural classes, and their corresponding ranks. **Parker (2002)** notes that more than 100 distinct sonority scales are found in the literature. The purpose of this section is to lay out several desirable characteristics that a full and final sonority hierarchy should possess, and then present one specific model that arguably comes closest to fulfilling those goals. Briefly, an adequate sonority scale should display the a priori traits in (26). In principle these criteria apply not just to sonority, but to all phonological features, that is, classic binary features like [±voice], [±round], etc.

(26) All else being equal, an ideal sonority scale would have these characteristics:

a. *Universal*: It potentially applies to all languages.

b. *Exhaustive*: It encompasses all categories of speech sounds.

c. *Impermutable*: Its rankings cannot be reversed (although they may be collapsed or ignored).

d. *Phonetically grounded*: It corresponds to some consistent, measurable physical parameter shared by all languages.

Each of the points in (26) will now be discussed. First, ideally we can establish a single, unique sonority hierarchy to analyze all known languages. This is not to say that any particular language actually exploits every one of the natural class rankings in the sonority scale. On the contrary, it would be quite amazing (although fortuitous) to discover such a case. Nevertheless, the explanatory power of sonority is maximized if we ascribe it to UG, making it equally available to all humans.

Second, an adequate theory of sonority should include every known type of phonological segment. Many hierarchies omit recalcitrant natural classes such as glottal consonants (/h/ and /ʔ/), affricates, etc., perhaps because of their inherent complications. Such scales then cannot apply to all languages. This undermines their universality.

Third, the rankings in the sonority scale should be impermutable. This is a beneficial characteristic since it is the most restrictive hypothesis possible, i.e. it severely limits the types of processes directly attributable to sonority. In addition to avoiding overgeneration of non-attested language types, impermutability makes claims about sonority easier to falsify. This in turn reduces the danger of circular argumentation. For example, once it is established that laterals, for instance, are more sonorous than nasals, the entailment is that there is no language in which nasals pattern as more sonorous than laterals by the same criteria. At the same time, however, potential divisions between sonority ranks are frequently underexploited in many languages. See **de Lacy (2002, 2004, 2006, 2007a)** for a formal approach to "underspecification" of sonority classes in OT.

Fourth, in an ideal world we can show that sonority is based on concrete articulatory gestures and/or their acoustic counterparts. This is the topic of the next section.

Although no sonority scale to date perfectly fulfills every desideratum sketched above, one that perhaps comes closest is that of **Parker (2008)**, reproduced below:

(27) *Final hierarchy of relative sonority*

| *Natural class* | *Sonority index* |
|---|---|
| low vowels | 17 |
| mid peripheral vowels (not [ə]) | 16 |
| high peripheral vowels (not [i]) | 15 |
| mid interior vowels ([ə]) | 14 |
| high interior vowels ([ɨ]) | 13 |
| glides | 12 |
| rhotic approximants ([ɹ]) | 11 |
| flaps | 10 |
| laterals | 9 |
| trills | 8 |
| nasals | 7 |
| voiced fricatives | 6 |
| voiced affricates | 5 |
| voiced stops | 4 |
| voiceless fricatives (including [h]) | 3 |
| voiceless affricates | 2 |
| voiceless stops (including [ʔ]) | 1 |

Space does not permit a detailed justification of (27). Nevertheless, to highlight a few positive aspects of this scale, the evidence for most of the natural classes is fairly robust and secure. **Parker (2002, 2008)** summarizes the debates and provides at least one argument to motivate every ranking in this hierarchy (every pair of adjacent categories). Much of this is reviewed in §2 of this chapter. To give another example, Koine (Ancient) Greek permits the clusters /pn/ and /kn/ (/pniktos/ '(things) strangled', /kneθo/ 'have itching, tickled'; **Mounce 1993**), but proscribes */bn/ and */dn/. This can be explained as an MSD effect if voiced stops are closer to nasals (in sonority) than voiceless stops are. Furthermore, flaps are higher in sonority than trills in Spanish, as established by the SCL in §2.3. Three other facts confirm this. First, in word-initial position the contrast between /r/ and /ɾ/ is neutralized to /r/ ([rana] 'frog'). Second, in codas it is neutralized in favor of /ɾ/: [tʃaɾlaɾ] 'to chat'. These two points follow from the SDP (**Bonet and Mascaró 1997**). Third, /ɾ/ and /l/ appear as the second member of complex onsets, yet /r/ does not (see (5)). This is another MSD effect if /r/ is less sonorous than ɾ and /l/ (**Baković 1994**). These distributional facts indicate that liquids do not always pattern as a monolithic class in Spanish. Finally, the rhotic approximant /ɹ/ is higher in sonority than /l/ in English: (1) the contrast between *Carl* (one syllable) *vs. caller* (two syllables) follows from the SSP if /ɹ/ outranks /l/ (**Borowsky 1986**); (2) /ɹ/ is the default epenthetic coda in Eastern Massachusetts speech (**McCarthy 1993**). This follows from the SDP if /ɹ/ is the most sonorous consonant available in this position. And (3) syllabic /ɹ/ may bear stress (*bird, curtain*), but /l/ never does (**Zec 2003**).

Another strength of the scale in (27) is its breadth, i.e. the number of different types of segment classes it encompasses. Nevertheless, it is still not exhaustive, because it leaves out a few rarer kinds of sounds, such as clicks and implosives. Since no known sonority hierarchy includes these, more research in this area would be welcome. A third advantage of (27) is that it has been rigorously tested and found to provide a good fit with all phonetic segments in seven specific languages. This is discussed in §5.

However, a few problems persist. For example, the placement of affricates between stops and fricatives is a controversial issue, remaining open to disagreement. Many scales either leave affricates out entirely or group them with plosives, using a term such as *stops*. Such proposals may simply assume that affricates behave phonologically like stops, as they do in many languages. For instance, Kang (**CHAPTER 95**: LOANWORD PHONOLOGY) concludes that affricates are just stops with a special place specification, e.g. [strident]. See **CHAPTER 16**: AFFRICATES for more discussion of affricates in general. Similarly, the ranking of voiced stops over voiceless fricatives is harder to justify than most aspects of this hierarchy. A major reason for this is that many languages require consonant clusters to agree in voicing. Therefore, crucial diagnostic examples are rare, but one such token is the English word *midst*. Since this form is monosyllabic, /d / is higher in sonority than /s/ by the SSP since /d/ is closer to the nucleus. Finally, the question of whether glottal consonants are sonorants or obstruents is also contested. Clearly /h/ and /ʔ/ pattern phonologically with prototypical sonorants in some languages, yet behave like obstruents in others. In (27) they are classified as obstruents. One piece of evidence supporting this is that in Panobo, /h/ groups with /β p t/ in exclusively obstruent + glide clusters (see (16)). Also, in many languages [ʔ] is inserted as a default onset, where segments of low sonority are preferred by the SDP (**Lombardi 2002**). Finally, in the P-base sample of 549 languages, there are 65 distinct phonological processes in which /h/ and/or /ʔ/ pattern solely with consonants that are unambiguously obstruents. In 21 other cases they group with sonorants (**Mielke 2008**).[6]

In the scale in (27) the tendency is obviously to "split" rather than to "lump together" natural classes. The motivation for this is as follows. There is ample evidence that fine-grade distinctions in sonority need to be made in some languages, such as between fricatives and stops in Sanskrit (§2.1). UG then must allow for these options, and hence the potential exists for other languages to exploit them as well. If we start with a hierarchy that assigns a unique rank to every distinct manner of articulation (like (27)), it is a trivial matter to formally compress (conflate) ranks together in order to analyze languages not invoking those splits. This procedure applies to every language in one way or another. However, if we assume a maximal sonority hierarchy with just the five groups in (3), no mechanism exists to "decompose" these, making more narrow distinctions in the scale when necessary. Consequently, only a fully detailed hierarchy such as (27) is flexible enough to generate the range of variation attested among the languages of the world with respect to processes involving sonority.

Nevertheless, based on acoustic studies of many languages, **Zhang (2001)** and **Gordon (2006)** deny that a universal sonority scale is theoretically the most parsimonious option. Rather, they reject the existence of invariant sound classes. Gordon, for instance, concludes that syllable weight effects are not a unified phenomenon. He claims that nasals, for example, display slightly different phonetic behavior from one language to another. This can then influence their phonological patterning in terms of sonority.

## 5 The physical substance of sonority

As summarized in §2, the function of sonority in phonological systems is fairly well understood. Nevertheless, these phenomena raise an important, related question that has provoked much contention and speculation: is there any coherent notion of sonority grounded in evidence external to the phonotactic facts that sonority is assumed to account for? In other words, what is the articulatory, acoustic, and/or perceptual source of sonority in the speech signal? To date at least 98 different correlates of sonority have been posited, documented in **Parker (2002)**. The most frequently proposed phonetic definition of sonority is probably openness (of the vocal tract) or (supralaryngeal) aperture (**Bloomfield 1914**; **Jespersen 1922**; **Goldsmith 1990**; **Kirchner 1998**), or its inverse, (supraglottal) stricture, closure, impedance, etc. (**Halle and Clements 1983**; **Kenstowicz 1994**; **Hume and Odden 1996**). However, notions such as impedance are difficult to quantify. A more promising correlate of sonority is amplitude/intensity, or its perceptual counterpart, loudness (**Bloomfield 1914**; **Laver 1994**; cf. §1 and see also **CHAPTER 98**: SPEECH PERCEPTION AND PHONOLOGY). Recently a major instrumental study was carried out measuring relative sound levels or RMS (root mean square) intensity of all phonemes of Peruvian Spanish, Cusco Quechua, and Midwestern American English (**Parker 2008**). See **Jany *et al.* (2007)** for a similar investigation of four other languages (Egyptian Arabic, Hindi, Mongolian, and Malayalam). In **Parker (2008)**, the obtained intensity values for all segments yield an overall mean Spearman's correlation of .91 with the sonority indices proposed in (27). Given those results, it is proposed there that the best way to characterize the physical basis of sonority is via a linear regression equation such as (28) below. This is calculated from the mean intensity measurements of all English coda consonants pertaining to nine of the natural classes from (27). These were pronounced five times each by five male native speakers of English.

(28) $sonority = 13.9 + .48 \times dB$ ($dB$ = decibel; $r^2 = .95$)

This formula predicts an estimated sonority index based on a hypothetical intensity value. It characterizes the best-fitting line corresponding to the relative sonority of English coda consonants in phrasally stressed words. The obtained intensity value of each of these segments was compared to that of a stressed, utterance-initial low vowel (/*a*/) in a fixed carrier sentence. In (28) the $Y$ intercept is 13.9. This is the projected value of $Y$ (sonority) when $X$ (dB) equals 0. Here it is significantly higher than the theoretical null value. This is because the obtained intensity of the reference vowel /*a*/, whose sonority index is 17, was subtracted from that of the target consonant for each utterance measured. This is a type of normalization procedure often performed to control for random fluctuations in loudness across speakers and tokens. The slope in (28), .48, indicates the rate of change in the dependent variable $Y$ (sonority) per unit change in the independent variable $X$ (dB). Its obtained value allows us to approximate the mathematical nature of the relationship between intensity and sonority. Specifically, for every decibel by which the relative sound level is increased, the corresponding sonority rank increases by about .48 units (for this sample of five English speakers). Also in (28), $r^2 = .95$. This is the coefficient of determination. It indicates the proportional reduction of error gained by using the linear regression model. Given this $r^2$ value, we can conclude that the single factor *sonority* accounts for (predicts) about 95 percent of the systematic variability in the intensity measurements of that dataset.

Compared with previous accounts of sonority, the definition in (28) has several advantages (**Parker 2008**): (1) it is precise; (2) it is non-arbitrary; (3) it is phonetically grounded; (4) it is empirically verifiable and replicable; (5) it can be calculated for other speakers and languages; and (6) the underlying methodology (regression) is compatible with different (competing) sonority scales. However, while studies of this type represent progress, some problems remain. For example, in **Parker (2008)** the majority of the mismatches between sonority ranks and segmental intensity values (in all three languages) involve the sonorant consonants, particularly the approximants (laterals and glides). The reason for this is not clear at this point and merits further investigation.

Finally, other researchers appeal to more functional aspects of the speech signal to avoid invoking sonority altogether. For example, building on the phonetically based work of **Mattingly (1981)** and **Silverman (1995)**, **Wright (2004**: 35) reformulates the SSP as "a perceptually motivated and scalar constraint in which an optimal ordering of segments is one that maximises robustness of encoding of perceptual cues to the segmental make-up of the utterance." Similarly, **Ohala (1990a)** claims that what drives the phonological phenomena discussed here is not really sonority but simply a need for adequate modulation in the acoustic wave.

## 6 Conclusion

Despite its problems, sonority makes sense. If it did not exist, it would be invented (**Parker 2008**). In this chapter a number of important issues have been examined. Nevertheless, certain topics need to be left for future work. For example, in §3 a possible contradiction between the claims of the MSD approach and the SDP is noted, involving the relative unmarkedness of OGV *vs.* OLV demisyllables. An in-depth typological study of these clusters would be helpful. Also, more attention should be given to the phonetic and/or functional bases of principles such as the SSP, the SCL, and the MSD. The question of why these hold true is potentially intriguing. Finally, another interesting point not discussed here is whether sonority scales are necessarily the same across different domains, such as phonotactics *vs.* the calculation of syllable weight.


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## Notes

1 Language names and genetic affiliations follow the *Ethnologue* (**Lewis 2009**). In the online version of this chapter, the appendix provides more details about the languages cited here: country, linguistic phylum, primary source of data, etc.

2 The online version of this chapter contains more illustrative data throughout.

3 Prenasalized stops (common in African languages) do not violate the SSP, since they are single phonemic units, not true sequences. Syllabic nasals, such as in hypothetical [n.da], do not constitute tautosyllabic onsets either.

4 Whitney does not gloss this root, but notes that the form is aorist.

5 The form /namra/ is preceded by *, since it is reconstructed.

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