

## Does sonority have a phonetic basis? Comments on the chapter by Bert Vaux

G. N. Clements

Laboratoire de Phonétique et Phonologie (LPP)  
CNRS/Sorbonne-nouvelle, Paris

In his chapter, Bert Vaux argues that syllabification conforms universally to the Sonority Sequencing Principle (SSP), according to which the segments in a syllable rise in sonority from the margin to the peak. Segments that cannot be gathered into syllables in this way remain extrasyllabic, linking to higher levels of prosodic structure such as the foot, the prosodic word, or the prosodic phrase.

The driving concept behind this view is that of *sonority*. Though this concept has a venerable history in phonology and phonetic studies, dating well back into the nineteenth century (Whitney 1865, Sievers 1881), precise phonetic correlates for it have proven elusive, and several scholars have maintained that it has no phonetic basis. This issue, which is not discussed by Vaux, is an important one, and I would like to comment on it briefly in these remarks.

As Vaux points out, not all phonological concepts have phonetic correlates. For example, though the syllable is an essential unit in phonology (and underlies many aspects of phonetic and prosodic patterning as well), it has no universally valid phonetic definition. This fact is not surprising once we recognize that the syllable is primarily a phonological construct, defined over sequences of discrete phonological segments rather than over phonetic primes as such. At this level of abstraction (which includes most of phonology), few constructs have direct phonetic definitions. Vaux rightly emphasizes that the ultimate justification for such concepts depends on their success in bringing order to a vast array of seemingly disparate facts. The syllable does just that.

Although sonority can also be justified on these grounds, it does not appear to be an abstract category in the same sense. It does not seem very likely that the ranking of various types of speech sounds in a sonority scale is entirely unrelated to their physical and perceptual properties. If sonority were completely abstract, as some linguists have maintained, a scale such as Vowel > Semivowel > Liquid > Nasal > Obstruent would be inherently arbitrary. We might just as well have expected syllables to conform to any random permutation of this scale, such as the (unattested) reverse order in which obstruents are the most favored syllable nucleus and vocoids the preferred margin. As I have pointed

out elsewhere, the absence of a consistent, physical basis for characterizing sonority in language-independent terms would make it impossible to explain the nearly identical nature of sonority constraints across languages (Clements 1990, 291).

Not all phoneticians maintain that sonority has no phonetic content, however. Many, from Sievers (1881) onward, have suggested that sonority is correlated in some way with audibility, in the sense that more audible sounds occupy a higher position on the sonority scale. This view was adopted in much subsequent work, for example by Heffner who stated that "sonority is a quality attributed to a sound on the basis of its seeming fullness or largeness, and when attributed to speech sounds, sonority is correlated very largely with the degree to which the voice is audible ... Sonority may be equated more or less correctly with acoustic energy and its quantities determined accurately by electronic methods" (Heffner 1950, 74). A similar view was proposed by Ladefoged (1993), who suggested that sonority can be defined in terms of the loudness of a sound, which is related to its acoustic energy relative to other sounds having the same length, stress, and pitch.<sup>1</sup>

Several methods of ranking speech sounds in terms of power and relative audibility have been described by Fletcher (1972, 82-86). Of the various measures proposed, the one that yields a result closest to the sonority scale is a composite measure of relative phonetic power, taking the power of the weakest sound as the basis of comparison. The ratio of powers between the weakest sound,  $\theta$ , and the most powerful sound,  $\varrho$ , is 680, amounting to a difference of 28 dB. The full ranking of English speech sounds is given in (1).

(1)

$\varrho$	680	u	310	tʃ	42	k	13
a	600	ɪ	260	n	36	v	12
ʌ	510	i	220	dʒ	23	ð	11
æ	490	r	210	ʒ	20	b	7
o	470	l	100	z	16	d	7
ʊ	460	ʃ	80	s	16	p	6
e	370	ŋ	73	t	15	f	5
ε	350	m	52	g	15	θ	1

It can be seen that by this measure, the relative ranking of English sounds is low vowels > mid vowels > high vowels > r > l > nasals > obstruents, with few discrepancies. This ranking fits commonly-proposed sonority scales quite well. The major anomaly is the high rank of voiceless sibilants, one of which, ʃ, outrank all nasals. Sibilants, though rather noisy sounds, do not pattern as high-sonority sounds in most languages. In English, for

example, they precede, rather than follow nasals in syllable onsets (*small*, *snail*, but *\*msail*, *\*nsail*).

I would like to suggest that sonority is related not to loudness or audibility as such, but to the relative *resonance* of speech sounds. While the words "sonority" and "resonance" overlap in their everyday meaning, resonance adds a suggestion of repetition to the base meaning of sonority (resonance = re + sonance). A resonant sound can be understood as one whose inherent sonority is repeated, prolonged or augmented in some way.<sup>2</sup>

Resonance is, of course, a familiar notion in both physics and acoustics. In acoustic theory, resonance is measured in terms of the amplitude at which an object vibrates at its natural frequency. In speech, resonance is a property of a vibrating body of air contained within one or more vocal tract cavities. In an acoustic system like the vocal tract, the natural frequencies (or resonances) of the vibrating air are determined by its size, shape and elasticity. Sounds perceived as sonorant tend to be characterized by a relatively low degree of resistance or acoustic loss, leading to a slow decay of formant oscillation, manifested in the spectrum as a reduction in formant bandwidth (i.e. as more sharply peaked formants). In contrast, sounds perceived as having low sonority have a relatively high degree of resistance or loss, leading to a faster decay of formant oscillation and a consequent increase in formant bandwidth (in the limit case, a flat spectrum).

The most resonant speech sounds are therefore those with a prominent, relatively undamped formant structure. Resonance is enhanced by voicing, which provides a strong and efficient excitation source: "the resonators respond to both ... hiss and voice, but generally with more sharply-tuned resonances – a greater concentration of acoustic energy into particular frequency bands – in voiced sounds, particularly vowels" (Catford 1977, 57). Sounds having this property include not only vowels, the resonants par excellence, but also semivowels, liquids and nasals – the traditional class of resonant consonants. Speech sounds not perceived as resonant do not have these properties, either because their resonances are not enhanced by voicing (as in voiceless vowels), or because they have a relatively flat spectrum (as in the case of most voiced fricatives). Resonance, in this sense, is not quite the same thing as loudness or audibility. Loud noises are audible by definition, but they are not necessarily resonant. For example, the chiming of a bell is resonant, but the hiss of a teakettle or the burst of a firecracker is not.

If we understand sonority in this sense, we may be in a better position to understand why the sonority scale has the form it has. Vowels stand at the top of the scale as they are characterized by a prominent, well-defined formant pattern. Other sonorants on the scale

have this property to a decreasing degree (Kent & Read 1992, Fujimura & Erickson 1997, and Stevens 1997):

- *approximant consonants* (liquids and semivowels) differ from vowels in generally having a reduced low-frequency spectrum amplitude, an additional decrease in amplitude at higher frequencies, and reduced prominence of the second or third formant peak;
- within the class of approximants, *liquids* differ from semivowels in having a brief, intermittent, or narrow constriction in the oral tract which further reduces their spectral energy and formant prominence;
- *nasals* differ from approximants in having a complete closure in the oral tract and an open passage to the nasal cavity, a configuration which creates a heavily damped nasal murmur of which only one component, the so-called nasal formant, has an amplitude comparable to that of vowel formants.

A further acoustic difference between laterals and nasals is that the nasals have a more abrupt transition to a neighboring vowel in the middle and high-frequency range, aligning them more closely with obstruents (Stevens & Keyser 1989). Obstruents, including sibilants, generally involve considerable noise (burst and/or frication), but little if any sustained resonance, though voiced obstruents, especially fricatives, often show some lower-frequency formants.

These differences among major sound types are reflected in the ranking of major sonority classes shown in (2), where all sonorants are understood as voiced, and all sounds but vowels are understood as nonsyllabic. Highest-sonority sounds occur at the top and lowest-sonority sounds at the bottom.

(2)	syllabic	vocoid	approximant	sonorant	"yes"
V (vowel)	yes	yes	yes	yes	4
S (semivowel)	no	yes	yes	yes	3
L (liquid)	no	no	yes	yes	2
N (nasal)	no	no	no	yes	1
O (obstruent)	no	no	no	no	0

As this chart shows, these classes are fully distinguished from each other by phonological features, except for vowels which are distinguished from semivowels by their function as syllable peaks. The positive value of each feature is generally more resonant than the negative value, all else being equal. A basic sonority hierarchy is created by this scale, quantifiable by the number of "yes" responses in each row as shown in the column at the

right (Clements 1990). More elaborate hierarchies recognizing subdivisions within these categories can (and have been) proposed, which depend on the specific characteristics of subclasses of these sounds. The sonority scale may thus be grounded in the perceived resonance of major classes of speech sounds, as defined in terms of the features shown at the head of each column in (2).

The main property just attributed to resonance – the presence of prominent formant peaks -- can also be considered defining properties of the feature [+sonorant].<sup>3</sup> The sonority scale then corresponds to the degree to which a given segment possesses the characteristic properties of [+sonorant] sounds. Vowels possess these properties to the highest degree and stand at the top of the scale, while (oral) stops and fricatives possess them to the lowest degree (or not at all) and stand at the bottom of the scale. Note that (2) does not include a column for voicing. Though sonorant sounds are typically voiced, we do not want to incorporate the feature [+voiced] into the definition of [+sonorant], as this would involve defining one feature in terms of another. Instead, we may consider voicing (like some minimum of duration) as a precondition for the perception of resonance in speech sounds. If this is correct, only voiced sounds count as [+sonorant], an analysis which seems generally consistent with crosslinguistic patterning.<sup>4</sup>

The view that sonority corresponds to perceived resonance provides a basis for understanding the way the sonority scale functions to organize segments into syllables. Some familiar principles of sonority-based syllabification are summarized below:

- (3) a. Sonority Sequencing: segments are syllabified in such a way that sonority increases from the margin to the peak
- b. Sonority-Syllabicity Alignment: sonority peaks correspond to syllable peaks and vice-versa
- c. Sonority Dispersion: sonority is maximally dispersed in the initial demisyllable and minimally dispersed in the final demisyllable
- d. Syllable Contact: sonority drops maximally across syllable boundaries

These principles express preferences rather than absolute laws: a syllable is highly valued to the extent that it conforms to these properties. Though violations of these principles do occur, the presence of a syllable violating one of them in a language usually implies the presence of otherwise similar syllables that do not, while the reverse is not true.

All these principles make sense if sonority is related to perceived resonance. Thus, for example, if sonority is based on perceived resonance, we can better understand why sonority peaks should constitute preferred syllable peaks, as required by Sonority-

Syllabicity Alignment (3b). Resonant sounds are optimal bearers of the prosodic properties that are typically associated with syllables. Vowels, as the highest-sonority sounds, are ideally suited to the function of anchoring the distinctive F0 variations found in tone, pitch-accent and intonation systems. Liquids and nasals may or may not constitute syllable peaks, depending on the language. While some languages, such as Tashlhiyt Berber as described by Dell & Elmedlaoui (2002), also allow obstruents to function as syllable peaks, such syllables poorly convey F0-based prosodic information, and this fact may have consequences for the prosodic system as whole. In the case of Berber, for instance, Dell & Elmedlaoui point out that significant pitch events are confined to sonorant peaks:

- (4) If Imdlawn Tashlhiyt has a phenomenon that could be called stress or accent, it is likely that it is a property of units larger than words. Our preliminary observations suggest that in general, the main pitch event in an intonational phrase occurs near its end, viz on the last or next-but-last syllable nucleus *which is a sonorant*. (Dell & Elmedlaoui 2002, 14; my italics)

One would have trouble imagining the opposite situation, in which the main pitch event in a language aligned with the last *non*-sonorant syllable nucleus. However, a fully abstract view of sonority would treat both situations as equally likely.

The view that sonority is based in perceived resonance may also help explain the preference for high-sonority final demisyllables (rhymes), as stated by the Sonority Dispersion principle (3c), after Clements (1990). Time-varying prosodic differences such as falling and rising tones are often sequenced across two segments of the syllable rhyme and can be most easily perceived if both members of the rhyme are high in sonority, i.e. if both are vowels or sonorants (Gordon 2004). Though stress-accent languages (in which contour tones do not occur) often allow obstruent-final syllables (English is an example), tone languages typically avoid them, and when they do have them, tonal distinctions are often neutralized on obstruent-final syllables. An example is present-day Hanoi Vietnamese, in which six tones contrast on sonorant-final syllables, but only two on syllables ending in one of the voiceless stops /p t k/ (Michaud 2004). Words illustrating each tone (with its traditional tone label and a brief description) are shown in (5).

## (5) a. sonorant-final syllables

ma	'ghost'	A1 (ngang)	High-level modal
mà	'which, whom'	A2 (huyền)	Low-falling modal
má	'cheek'	B1 (sắc)	High-rising modal
mạ	'young rice plant'	B2 (ngặng)	High-falling glottalized
mả	'tomb'	C1 (hỏi)	High-falling rising modal; (other speakers:) Falling with final laryngealization
mã	'plumage; code'	C2 (ngã)	Falling-rising with medial glottal constriction

## b. stop-final syllables

mát	'fresh; refreshing'	D1 (sắc)	High-rising modal
mạt	'sawdust'	D2 (ngặng)	High-falling modal

It will be noted that not only the pitch of the tones, but also their laryngeal quality is neutralized in stop-final syllables, whose tones are produced with modal voice.

A further sonority-related principle of syllables is Syllable Contact (3d) which favors a maximal drop in sonority across a syllable boundary (e.g. Murray & Vennemann 1983, Vennemann 1988). This principle prefers the syllabification of a word like *metro* as *me.tro* rather than *met.ro*, since sonority drops from *e* to *t* in the first syllabification but rises from *t* to *r* in the second. It predicts that syllable sequences should be favored across languages to the extent that the drop in sonority across syllable boundaries is large, except where language-particular constraints on syllable structure override it (for example, *met.ro* would be preferred to *me.tro* in languages which systematically disallow complex onsets). The Syllable Contact principle, like Sonority Sequencing (3a), may facilitate parsing of the syllable nucleus, as a sharp drop in sonority from a nucleus to a following onset will typically coincide with the point at which prosodic information *ceases* to be linguistically relevant.

Not all these principles are independent, of course. In particular, the Syllable Contact principle (3d) is closely related to Sonority Dispersion (3c) and may derive from it, at least in part. This is because the syllable sequences preferred by the Syllable Contact principle are generally those whose individual syllables, taken in isolation, are preferred by the Sonority Dispersion principle. (To see this point, consider again the preferred syllabification *me.tro*; both syllables conform to Sonority Dispersion in having low-sonority initials and high-sonority finals, but it is just because of this that their combination satisfies the requirements of Syllable Contact.) The main argument for treating these two principles as independent is that many languages, including English, French and Vietnamese, allow word-final stops and fricatives quite freely, creating syllables which

violate Sonority Dispersion while not infringing Syllable Contact. However, few languages favor obstruent-final syllables over sonorant-final syllables, and those that allow them usually place heavy restrictions on them, as does English. Furthermore, as pointed out by Vaux, in a number of languages, such as Icelandic, word-final consonants behave as extrasyllabic, in which case they do not count as syllable codas at all. Thus there is good reason to believe that Sonority Dispersion operates on codas even in languages that at first sight seem to show the opposite.

To summarize, it appears that sonority plays a fundamental role in accounting for preferred phonotactic patterns across languages and that this role may reflect its basis in relative power or perceived resonance. At the same time, however, it is necessary to point out that sonority does not explain everything (an alleged shortcoming of sonority theory according to some critics), and to mention a few things that it does *not* do.

First, sonority theory does not explain all phonotactic patterns – nor was it ever intended to. Many common constraints have little or nothing to do with syllable structure, and lie entirely outside the domain of sonority theory. One example is the common constraint which requires obstruent clusters to agree in voicing. This constraint operates not only within syllable constituents but across syllable boundaries in many languages (e.g. French, Russian, Catalan), showing that it can be entirely independent of syllabification. Furthermore, some syllable-based constraints have nothing to do with sonority. An example here is the common rule of obstruent devoicing in syllable codas; this phenomenon is unrelated to sonority, since devoicing makes the coda less, rather than more sonorant, contrary to Sonority Dispersion (3c). Sonority-based syllabification is just one among many interacting principles that together account for trends in phonotactic patterning.

Second, the constraints in (3) are not exceptionless "laws" but several of a number of constraints that interact, and occasionally compete, to favor some syllabifications over others. Thus, as mentioned above, one constraint that often overrides the Syllable Contact principle (3d) is the prohibition of complex syllable onsets. Turkish provides an example. In this language, sonority sequencing plays a role in determining the set of possible word-final clusters. If a cluster consists of a sonorant + obstruent (or ends in one of a small set of obstruent clusters), it is well-formed and requires no epenthetic vowel (6a). In all other cases, an epenthetic vowel, showing the expected vowel harmony, appears between its two members ("nominative" column of (6b)). The accusative forms shown in the "accusative" column show that no epenthetic vowel appears when the cluster is intervocalic. The forms in (6c) are included to show that underlying vowels are not deleted in the accusative.



(6)		<i>nominative</i>	<i>accusative</i>	<i>underlying</i>
a.	'Turk'	türk	türk-ü	/türk/
	'steep'	sarp	sarp-i	/sarp/
	'color'	renk	reng-i	/reng/
b.	'text'	metin	metn-i	/metn/
	'belly'	koyun	koyn-u	/koyn/
	'idea'	fikir	fikr-i	/fikir/
c.	'copper'	bakır	bakır-i	/bakır/
	'poor'	fakir	fakir-i	/fakir/
	'sheep'	koyun	koyun-u	/koyun/

Sonority Sequencing thus requires epenthesis in word-final clusters with poor sonority profiles, even when such epenthesis merges underlying minimal pairs ('belly' vs. 'sheep').

Since sonority requirements apply word-finally in Turkish we might expect them to control word-internal clusters as well. However, this is not the case. All intervocalic clusters are separated by a syllable boundary (C.C), regardless of their segmental composition, due to a more basic constraint which rules out complex onsets. As a result, intervocalic clusters systematically disobey Syllable Contact, as is shown by examples like *an.la* 'understand' or *mıs.ra:* 'poem line'. The Complex Onset constraint operates with full generality in Turkish, ruling out word-initial clusters in the native vocabulary, and explaining the fact that initial clusters in loanwords are ordinarily separated by an epenthetic vowel (e.g. *pirens* 'prince'). It also explains the fact that obstruents undergo devoicing both word-finally and before other consonants, since in both cases they occupy coda position (e.g. *kap / kaplar* 'container' (sg. / pl.), cf. *kaba* (dative), *kabı* (possessed)). In addition, it accounts for a more subtle observation regarding compensatory lengthening. As Sezer (1985) points out, the consonants /v, h, y/ optionally delete under certain conditions. When they do, the preceding vowel may undergo compensatory lengthening, but only if the deleted consonant occupies the syllable coda in the corresponding full form which is its source (7a). If the deleted consonant is in the onset, the preceding vowel does not lengthen (7b).

(7)	a.	savmak ~	sa:mak	'to get rid of'
		övmek ~	ö:mek	'praise'
		kahya ~	ka:ya	'steward'

b.	davul	~	daul	'drum'
	tohum	~	toum	'seed'
	ishal	~	isal	'diarrhea'

The fact that the vowel lengthens in a word like [sa:mak], derived from /savmak/, confirms that the syllabification prior to *v*-deletion is *sav.mak*, with *v* in the coda as required by the Complex Onset constraint. To summarize, we see that the latter constraint systematically takes precedence over the Syllable Contact constraint in Turkish.

A third necessary qualification is that the principles in (3) need not apply as uniform, all-or-nothing constraints. Although earlier analyses have occasionally treated them as such, attempts to apply these principles to complex data have shown that they may have to be parceled into a family of more specific constraints applying to specific subparts of the syllable (onset, coda, initial demisyllable, final demisyllable, etc.), or to specific types of violations (sonority reversals vs. sonority plateaux, etc). Exactly what this family of constraints might consist of is a subject of ongoing research (for suggestions, see Zec 1995, Clements 1997, Davis & Shin 1999, Dell & Elmedlaoui 2002, and Green 2003, among others).

In conclusion, Bert Vaux has provided a very useful overview of the evidence for the appendix, emphasizing the wide variety of phenomena that it helps to explain. While I agree with his analysis in most respects, I have suggested that the notion of sonority which underlies his syllabification algorithm is not phonetically undefinable, but may be rooted in the property of perceived resonance. These remarks are admittedly tentative and it is hoped that future experimental studies will be able to test them and to correct them as necessary.

**Acknowledgements.** I would like to thank François Dell and Shinji Maeda for helpful correspondence on an earlier version of these comments, as well as Alexis Michaud for assistance with the Vietnamese examples.

## Notes

- <sup>1</sup> Other phoneticians, from Jespersen (1932) to Beckman et al. (1992), have related sonority to the degree of opening of the vocal tract.
- <sup>2</sup> In a related suggestion, Nathan (1989) has proposed that sonority is a function of relative loudness, voicing, *svara* (formant structure), and prolongability.
- <sup>3</sup> For reasons discussed in Clements & Osu 2002, [sonorant] and [obstruent] may constitute distinct features.
- <sup>4</sup> This analysis can be stated formally as a constraint against the feature combination \*[+sonorant,-voiced]. It appears that many, if not all so-called voiceless sonorants can be better analyzed as bearing the feature [spread glottis] (e.g. Lombardi 1993, Clements 2003); whether these sounds ever pattern as true sonorants remains an open question.

## References

- Beckman, Mary, Jan Edwards, & Janet Fletcher. 1992. "Prosodic structure and tempo in a sonority model of articulatory dynamics." In Gerard J. Docherty & D. Robert Ladd, eds., *Papers in Laboratory Phonology II : Gesture, Segment, Prosody*, 68-86. Cambridge: Cambridge University Press.
- Catford, J.C. 1977. *Fundamental Problems in Phonetics*. Bloomington: Indiana University Press.
- Clements, G. N. 1990. "The role of the sonority cycle in core syllabification." In John Kingston & Mary Beckman, eds., *Papers in Laboratory Phonology I*, 283-333. Cambridge: Cambridge University Press.
- Clements, G. N. 1997. "Berber syllabification: derivations or constraints?" In Iggy M. Roca, ed. *Derivations and Constraints in Phonology*, 289-330. Oxford: Oxford University Press.
- Clements, G. N. 2003. "Feature Economy in Sound Systems", *Phonology* 20.3, 287-333.
- Clements, G. N. & Sylvester Osu. 2002. "Explosives, implosives, and nonexplosives: the linguistic function of air pressure differences in stops". In Carlos Gussenhoven & Natasha Warner, eds., *Laboratory Phonology 7*, 299-350. Berlin: Mouton de Gruyter.
- Davis, Stuart & Seung-Hoon Shin. 1999. "The syllable contact constraint in Korean: An optimality-theoretic analysis," *Journal of East Asian Linguistics* 8, 285-312.
- Dell, François & Mohamed Elmedlaoui. 2002. *Syllables in Tashlhiyt Berber and in Moroccan Arabic*. Dordrecht: Kluwer.
- Fletcher, Harvey. 1972. *Speech and Hearing in Communication*. Huntington: Robert E. Krieger.
- Fujimura, Osamu & Donna Erickson. 1997. "Acoustic phonetics." In William J. Hardcastle & John Laver, eds., *The Handbook of Phonetic Sciences*, 65-115. Oxford: Blackwell.
- Gordon, Matthew. 2004. "Syllable weight." In Bruce Hayes, Robert Kirchner, & Donca Steriade (eds.), *Phonetic Bases for Phonological Markedness*, 277-312. Cambridge: Cambridge University Press.

- Green, Anthony Dubach. 2003. "Extrasyllabic consonants and onset well-formedness." In Caroline Féry & Ruben van de Vijver, eds., *The Syllable in Optimality Theory*, 238-253. Cambridge: Cambridge University Press.
- Heffner, R-M. S. 1950. *General Phonetics*. Madison: The University of Wisconsin Press.
- Jespersen, Otto. 1932. *Lehrbuch der Phonetik*. Funfte Auflage. Leipzig and Berlin: B.G. Tuebner.
- Kent, Ray D. & Charles Read. 1992. *The Acoustic Analysis of Speech*. San Diego: Singular Publishing.
- Ladefoged, Peter. 1993. *A Course in Phonetics*, 3rd edition (International Edition). Orlando: Harcourt Brace & Company.
- Lombardi, Linda. 1994. *Laryngeal features and laryngeal neutralization*. New York: Garland.
- Michaud, Alexis. 2004. "Final consonants and glottalization: new perspectives from Hanoi Vietnamese," *Phonetica* 61, 119-146.
- Murray, R.W. & Theo Vennemann. 1983. "Sound change and syllable structure in Germanic phonology," *Language* 59, 514-528.
- Nathan, Geoffrey S. 1989. "Preliminaries to a theory of phonological substance: the substance of sonority." In Roberta Corrigan, Fred Eckman, & Michael Noonan, eds., *Linguistic Categorization*, 56-67. Amsterdam/Philadelphia: John Benjamins.
- Sezer, Engin. 1985. "An autosegmental analysis of compensatory lengthening in Turkish." In Leo Wetzels & Engin Sezer, eds., *Studies in Compensatory Lengthening*, 227-250. Dordrecht: Foris Publications.
- Sievers, Eduard. 1881. *Grundzüge der Phonetik*. Leipzig: Breitkopf und Hartel.
- Stevens, Kenneth N. 1997. "Articulatory-acoustic-auditory relationships." In William J. Hardcastle & John Laver, eds., *The Handbook of Phonetic Sciences*, 462-506. Oxford: Blackwell.
- Stevens, Kenneth N. & S. Jay Keyser. 1989. "Primary features and their enhancement in consonants," *Language* 65.1, 81-106.
- Vaux, Bert (this volume) "The appendix"

- Vennemann, Theo. 1988. *Preference Laws for Syllable Structure and the Explanation of Sound Change*. Berlin: Mouton de Gruyter.
- Whitney, William Dwight. 1865. "The relation of vowel and consonant," *Journal of the American Oriental Society*, vol. 8. Reprinted in W. D. Whitney, 1874: *Oriental and Linguistic Studies*, Second Series, Charles Scribner's Sons, New York.
- Zec, Draga. 1995. "Sonority constraints on syllable structure," *Phonology* 12, 85-129.