1 Underlying Representations

Jennifer Cole
José Ignacio Hualde

Language is acquired and experienced primarily through the medium of speech or the manually signed signal. A primary goal of phonology, restricted here to the context of spoken language, is to discover the elements that serve as the building blocks of speech. Considering that languages differ in their spoken forms, two further questions for an understanding of phonology concern the relations between the sound elements that give shape to the phonological system of an individual language, and the constraints that determine how these sound elements may pattern in the formation of words and phrases in that language.

Over many centuries of scholarship and across continents, linguists have pursued answers to these questions for the practical purpose of providing a straightforward orthography for particular languages (see Pike 1947), explicating a method for describing the phonological component of individual languages, or for the scientific purpose of identifying the mental encoding of phonological form in the minds of the native speaker/hearer. Differences in the relative priority accorded to practical and scientific purposes have resulted in differences in the principles and methods of competing schools of phonology. But all approaches, from the work of the Sanskrit scholar Patanjali in the second century BCE to the theories that emerged during the heyday of European and American phonology in the twentieth century, presume that the basic elements of spoken language are at some level of abstraction from the physical form of speech as experienced by the speaker/hearer. The representation of words in terms of abstract elements is posited as a *basic* or *underlying representation* (UR) in nearly every phonological theory to the present day. Theories differ in the status of the UR (as an artifact of descriptive analysis, or part of the cognitive system of language), its relation to morphological form and phonetics, and whether it may encode morphosyntactic context, reflecting differences among theories in the kinds of data considered as primary evidence for phonological form. Different proposals for UR also reflect differences in the scope of the proposed theory, e.g. in modeling diachronic or synchronic phenomena, dialectal or style-dependent variation, corpus data, speaker intuitions, child productions, or instances of the intentional, creative manipulation of phonology in poetry or language games.

1 Underlying representations in phonemic theories

Phonological theories of the late nineteenth and early twentieth century take the *phoneme* as the basic element of phonological analysis (see CHAPTER 11: THE PHONEME). Jan Niecisław Baudouin de Courtenay and his student Mikołaj Kruszewski of the Kazan school (established in the mid-1870s) introduced the phoneme as a mental construct encoding the "image" of a sound as it is perceived and recognized, and as the abstract units with which phonological alternations may be characterized (Baudouin de Courtenay 1871). The notion of the phoneme as an abstraction from the acoustic and articulatory manifestation of speech was also expressed in the contemporaneous work of Ferdinand de Saussure, published posthumously in 1916, and recognized as the origin of structuralist linguistic analysis. De Saussure's "sound images," corresponding to what other scholars would term "phonemes" (Anderson 1985: 38–40), were characterized in terms of the properties that distinguish between the abstract sound units. And while Baudouin de Courtenay's view evolved to assign psychological reality to the phoneme as a unit of representation, de Saussure did not share this attribution, emphasizing instead the importance of the rules that relate sound representations (Anderson 1985: 53, 68). Despite de Saussure's rejection of the phoneme as constituting a distinct level of representation – an underlying form – his work profoundly influenced a later generation of scholars who focused intensely on the question of phonemes as units of representation, notably in the work of Trubetzkoy (1939) and Jakobson (1949) of the Prague School and of American structuralist linguists such as Bloomfield (1933) and Harris (1944, 1960).

Both the Prague School and American structuralism adopted de Saussure's view of phonemes as being characterized in terms of a system of contrast (see CHAPTER 2: CONTRAST). The Prague School notion was that phonemes are elements that are related to one another in a system of oppositions that define lexical contrast. Similarly, Jones (1967: 10) defines the phoneme as "a family of sounds in a given language which are related in character and are used in such a way that no one member ever occurs in a word in the same phonetic context as any other member," and explains that what phonemes do "is to distinguish words from one another" (1967: 265). The American structuralists held a similar notion, and focused on the method for determining the phonemic representation of words based on observations of phonetic form.

In a first sense, any representation of the utterances of a language in terms of contrasting phonemes can be construed as providing an *underlying* representation of those utterances. Thus, the form **'fonim**, which we find in Kenyon and Knott's (1953) *Pronouncing dictionary of American English* for what is conventionally written *phoneme*, is to be taken as the representation that underlies the infinitely diverse actual and potential productions of this word by native speakers of American English. This UR is in terms of the contrasting segment-sized units of the language.

An important claim behind phonemic theories, by and large borne out by everyday experience, is that, given an adequate phonemic representation, a native speaker of the language will know how to pronounce a previously unknown word accurately, in all phonetic detail. That is, a native speaker of American English who encounters, say, the word *phoneme* for the first time in an English text will know

how to pronounce it accurately upon consulting Kenyon and Knott's dictionary. Words containing the same sequence of phonemes cannot differ in any detail of their pronunciation. If they do, that would indicate that they have been incorrectly transcribed as having identical underlying phonemic representations. In the case of a language whose conventional orthography follows the phonemic principle to a greater extent than English, such as Spanish, it is not unusual for very small children to convincingly read the newspaper aloud even though a great percentage of the words that they are reading may be unknown to them (so that, in fact, they may not understand much of what they are reading).

A first hypothesis of the theory of phonemic transcription is thus that all utterances in a language can be analyzed as combinations of a small set of phonemes (consonants, vowels, and prosodic phonemes). Often there is an important additional hypothesis that there is a universal set of sounds among which each actual language chooses its set of contrasting phonemes. The International Phonetic Alphabet (IPA) represents an explicit proposal about the nature of this universal set. As stated in the *Handbook of the International Phonetic Association* (IPA 1999), "[t]he IPA is intended to be a set of symbols to represent all the possible sounds of the world's languages [. . .]. The sounds that are represented by the symbols are primarily those that serve to distinguish one word from another in a language" (IPA 1999: 159).

Everyday experience shows that, on the other hand, there is no universal phonetics. To give a trivial example, one of the authors of this chapter is a native speaker of American English and the other one is a native speaker of Spanish who learned English in adulthood. Both authors have a good understanding of what sounds the symbols of the IPA are intended to represent. Chances are that both authors' renditions of a given word in American English, say, **'fonim**, would be identified as the same sequence of phonemes, that is, as the word that is normally written *phoneme*. One of them, however, would be perceived as having been produced with a foreign accent (i.e. with non-native phonetics).

The implicit hypothesis of phonemic transcription, e.g. as reflected in Kenyon and Knott, is, then, that speakers' knowledge of the sounds of their language can be characterized as (a) knowledge of the phonemes and sequences of phonemes of their language (drawn form a larger potential set of contrastive sounds, as expressed in the IPA), and (b) knowledge of how to articulate those phonemes in the different phonological environments in which they can be found. Importantly, phonetic detail can be abstracted away from individual lexical entries. Given a UR consisting of a string of phonemes, a native speaker will know how to pronounce it in all contexts.

2 Indeterminacy in phonemic representations

Experience has shown that establishing the phonemic inventory of a language is for the most part a straightforward matter, but also that in any language there usually remain a few cases of unclear or ambiguous phonemicization (cf. for instance, Hualde 2004). Difficulties often arise in situations where the mapping between allophones and phonemes is not one-to-one (i.e. the *bi-uniqueness condition* of Harris 1944, 1951 breaks down). Some of the commonly attested types of problems for phonemicization are discussed in this section.

2.1 *English flaps as "fuzzy" phonemes*

Indeterminacy in phonemic analysis arises when a single surface segment can be analyzed as deriving from a sequence of two phonemes and when segmentation as one or two phonemes is unclear. There are well-known examples of this sort in English, such as the case of the rhotacized vowel that occurs in words like *bird* – is it an independent phoneme or a sequence of vowel followed by /r/? A similar question occurs for the velar nasal – is it an independent phoneme with defective distribution (banned from syllable-initial position) or the phoneme sequence /ng/? Another notorious problem for segmentation is posed by the tense, diphthongizing vowels, variously transcribed with one or two symbols by different authors. A distinct kind of problem for phonemicization concerns the treatment of schwa – should it be analyzed as an allophone of /ʌ/ (a phonetically similar vowel) that occurs in unstressed syllables? Or, in cases where there is a morphologically related word in which stress occurs on a different syllable (e.g. *'tel*[ə]*phone*, *te'l*[ɛ]*phony*), should the phonemicization of schwa depend on the value of the corresponding vowel in the related word? We will come back to this topic.

A different issue for phonemic analysis is that of the status of the flap [ɾ] in American English (see also CHAPTER 113: FLAPPING IN AMERICAN ENGLISH). Replacing [ɾ] with [t^{h}] in *be**tt**er*, *bu**t** again*, or *posi**t**ive* does not result in a difference in lexical meaning, so by an analysis based on the test of lexical contrast, [ɾ] should be an allophone of /t/. But under Harris's (1951) criterion of the native speaker's judgment, the flap may qualify as a phoneme, since native speakers are aware that these are two different sounds (as reflected, for instance, in informal spellings such as *geddout of here*, *forgeddabouddit*, etc.).[1] The perceived difference may be associated with formality or personal choice (in *better*, *positive*), or with phrasing (in *but again*). If we consider the phoneme as a sound category, then the flap in American English appears to be an example of a "fuzzy" or quasi-phoneme that shares some but not all of the properties of more robust phonemes (see Janda 1999 and Hall 2009 for related discussion). This view treats phonemicization as being akin to other categorization phenomena (Taylor 2006), and may allow for more complexity in the relationships among linguistic sounds than that implied in any of the twentieth-century phonemic theories.

2.2 *Neutralization*

2.2.1 *English obstruent sequences*

As noted, phonemic theory invokes lexical contrast as a primary criterion for establishing the phonemic status of a sound relative to other sounds in the language. Problems for this approach arise when contrast relations between two or more sounds are not consistent throughout the language. For instance, in many languages, two or more sounds that contrast in some positions in a syllable or word fail to contrast in others. This phenomenon is known as the *neutralization* of contrast, and its resolution in phonemic analysis has led to increased abstraction in URs in several theories.

Consider the case of obstruent voicing in English. In English, coda sequences of obstruents always agree in voicing. Thus we observe obstruent voicing agreement

[1] Flapping causes neutralization of /t/ and /d/. Speakers also seem to be aware that the flap is different from /d/, although we don't have the same kind of evidence.

in words like *act* and *tasks*, while the corresponding disagreeing tautosyllabic sequences are unattested, */-kd/, */-zks/, etc. In a simple phonemic analysis (i.e. one that expresses only phonemes and allophones and a direct mapping between the two), the absence of clusters with disagreeing voicing results in a pattern of defective distribution of obstruents: only voiced obstruents occur adjacent to a tautosyllabic voiced obstruent, with a parallel restriction for voiceless obstruents. The defective distribution does not, in this simple phonemic analysis, have any implications for URs, nor is it explicitly treated in the phonemic analysis.

Prague School phonology, on the other hand, offers an explicit model of neutralization by positing an archiphoneme in the phonological representation (the UR) in contexts of neutralization. An archiphoneme is a unit that represents the common features of phonemes whose contrastive property is neutralized in specific contexts. The archiphoneme appears in only those contexts of neutralization, substituting as it were for any one of the specific phonemes it covers. In the English example under discussion here, in a sequence of obstruents in the syllable coda, archiphonemes unspecified for voicing (represented by capital letters) replace any occurrence of an obstruent phoneme after another obstruent. In English we would thus have representations such as *desks* /dɛsGZ/, *texts* /tɛkZDZ/, *adze*, *ads*, *adds* /ædZ/, etc., where the surface voice properties of the archiphoneme are predictable from the preceding context. The inclusion of archiphonemes renders URs somewhat more abstract than a simple phonemic representation, and anticipates future developments advocating abstractness of URs. But before leaving this example, notice that since the neutralization of obstruent voicing may affect consonants across morpheme boundaries in coda clusters, as in *texts*, *ads*, and *adds*, it leads to alternations in the shape of suffixes including the regular plural nominal suffix and the 3rd person verbal agreement, a topic to which we will return in §3.

2.2.2 *Japanese sibilants*

The treatment of neutralization in phonemic theory has further implications for the abstractness of URs, illustrated here in an example from Japanese. In Japanese [s] and [ʃ] appear to be in phonemic contrast in all contexts except before /i/, where only [ʃ] is found, and before /e/, where only /s/ is found, excluding recent borrowings. Thus Japanese presents another case of the defective distribution of phonemes due to the neutralization of contrast in specific contexts. In a Prague School analysis the archiphoneme /S/ would replace the two phonemes /s/ and /ʃ/ before a front vowel, where the contrast is neutralized.

There is another possible solution to phonemicization in cases of defective distribution such as the Japanese example, which does not involve archiphonemes. The solution allows the specification in UR of abstract phonemes that fail to map to surface allophones.[2] We refer to this here as the Abstract Phonemic analysis. For the Japanese case, an Abstract Phonemic analysis posits the phoneme /s/, relegating [ʃ] to the status of an allophone: /s/ maps onto the allophone [ʃ] in surface realization when it precedes phonemic /i/ and also before the glide /j/, a kind of "ghost" phoneme that serves to condition the palatal sibilant and is simultaneously absorbed into that consonant (see Table 1.1). In fact, there is a romanization of Japanese that assumes this second phonemicization, and this is essentially the representation that we also find in the native kana orthography.

[2] Goldsmith (2008) presents an insightful discussion of the historic precedent for this type of analysis in the work of Harris (1951).

Table 1.1 Phonemicization of Japanese surface allophones [s ʃ] in three phonemic analyses. Representations in parentheses are excluded from the set of possible URs

Surface allophones		*Simple phonemic*		*Prague School*		*Abstract phonemic*	
		phonemes: /s ʃ/		*phonemes:* /s ʃ/ *archiphoneme:* /S/		*phonemes:* /s/	
[sa]	[ʃa]	/sa/	/ʃa/	/sa/	/ʃa/	/sa/	/sja/
[se]	—	/se/	(*/ʃe/)	/Se/	(*/se ʃi/)	/se/	(*/sje/)
—	[ʃi]	(*/si/)	/ʃi/	/Si/	(*/si ʃi/)	/si/	(*/sji/)
[so]	[ʃo]	/so/	/ʃo/	/so/	/ʃo/	/so/	/sjo/
[sɯ]	[ʃɯ]	/sɯ/	/ʃɯ/	/sɯ/	/ʃɯ/	/sɯ/	/sjɯ/

2.3 *Basque palatal sonorants and the question of the "free ride"*

A similar situation arises in Basque. In some Basque dialects /l/ and /n/ historically became [ʎ] and [ɲ], respectively, when preceded by /i/, syllabic or non-syllabic, and followed by another vowel; e.g. [mutila] > [mutiʎa] 'the boy', [mina] > [miɲa] 'the pain'. When the trigger was a glide, it was absorbed: [sajna] > [saɲa] 'the vein'. Since, in the relevant varieties, /l/ and /n/ were not palatalized in the coda, this has resulted in numerous alternations in morpheme-final position: [mutil] 'boy', [mutiʎa] 'the boy'; [min] 'pain', [miɲa] 'the pain'; [sajl] 'difficult', [saʎa] 'the difficult one'; [sajn] 'vein', [saɲa] 'the vein' (in other dialects we find palatalization also in the coda). In a phonemic analysis with ordered rules, this mapping between phonemic and allophonic representation could be handled by the following ordered rules (glides are allophones of the high vowels and another rule would account for their distribution; see CHAPTER 15: GLIDES):[3]

(1) *Basque palatalization*

Palatalization:	/l n/ → [ʎ ɲ] in contexts following /i j/ and preceding a vowel
Glide absorption:	/j/ deletes in contexts preceding (intermediate) [ʎ ɲ]
	e.g. /mina/ → [miɲa]
	/saila/ → sajla → sajʎa → [saʎa]

Once we have these rules, we may let them apply also in the morpheme-internal context, where palatals do not participate in any alternations. Thus, [iʎe] 'hair', [oʎo] 'chicken', [iɲor] 'anybody', and [baɲatu] 'bathe' can be analyzed as /ile/, /oilo/, /inor/, and /bainatu/. The rules in (1) will successfully derive palatal sonorants from all positions except perhaps word-initially (where the context for the added rule of glide formation would not obtain); since word-initial palatal sonorants are found only in a very small number of words (mostly borrowings),

[3] Phonemic analyses with ordered rules mapping phonemes to surface allophonic representations are found in Bloomfield (1939), and, as highlighted in Goldsmith's recent work (2008), are again taken up by Wells (1949) in work that presages the major development in Generative Phonology a decade later.

this dynamic phonemic analysis may allow us to dispense with two phonemes, /ʎ ɲ/, from the underlying phoneme inventory for the language. The question for phonemic theory is whether this analysis should be allowed, where morpheme-internal palatal sonorants get a "free ride" on the analysis motivated for cross-morpheme contexts (Oñederra 1991). In this particular case, we have some evidence in favor of the abstract analysis that allows "free ride" derivations, in the form of some subsequent developments. In a couple of regional dialects palatal sonorants have undergone depalatalization, and this has affected both morpheme-final and morpheme-internal palatals. Indeed, palatals which did not have their historical origin in the palatalization process have also been depalatalized, generating a preceding glide when not following /i/: e.g. *teila* 'tile' < Romance *teʎa; *ladrilu* 'brick' < Spanish *ladrillo*; *dainu* 'damage' < Spanish *daño* (Zuazo 2010: 61–62). Although the explanation for this second sound change may be found in a hypercorrection process, it is consistent with the abstract URs of the "free ride" analysis.

2.4 Summary

The examples discussed above illustrate the challenge in determining the correct UR for a given word or phrase in a phonemic analysis. While there has been widespread support for the notion that the basic elements of phonology are units, such as phonemes, that are abstractions over detailed phonetic forms, there are still many questions remaining about the degree of abstraction that is appropriate in UR. A frequent problem arises when two sounds that contrast in some contexts do not contrast in other contexts, as in the Japanese example that we have considered. Further issues arise from the possibility of reducing the size of the phoneme inventory at the expense of greater abstractness in underlying phonemic representation, as in the case of Basque palatal sonorants, or the several problematic cases mentioned from English. Yet another challenge arises from cases where different criteria for phonemicization result in conflicting phonemicization, as in the case of the English flap as a fuzzy phoneme. Yet other challenges arise when the contrast between lexical items involves overlapping segments, and cannot be reduced to an analysis in terms of one-to-one correspondence between phones and phonemes (for further discussion see Lass 1984: ch. 2).

3 Underlying representations in morphophonemic theories

A different approach to phonemic analysis in cases of neutralization can be found in the work of American structuralist phonologists who tackle the problem of determining the underlying segments in cases of neutralization by taking into consideration the phonological form of inflectionally or derivationally related words. A classic demonstration of this approach is in the analysis of the underlying voicing of word-final plosives in German, based on their realization in inflected forms of the same paradigm. For instance, the final voiceless consonant of *Bund* [bʊnt] 'association' may be analyzed as the realization of an underlying voiced phoneme /d/, because the genitive *Bundes* [bʊndəs] appears with the voiced phoneme, as does the plural *Bunde* [bʊndə] (see CHAPTER 69: FINAL DEVOICING AND FINAL LARYNGEAL NEUTRALIZATION). Similarly, American English *atom* [æɾəm] may be represented

as /ætɑm/ because the underlying nature of the neutralized segments is revealed in *atomic* [ətʰɑmɪk]. This view, which makes use of morphophonological considerations to determine underlying forms, was already present in the work of Baudouin de Courtenay (see Anderson 1985: 67–68), but is explicitly rejected by Jones (1967: 104–107) and other authors who maintain that phonemic representations of words should be established using purely phonological information.

In American structuralist approaches, a phonemic representation is based on observations of the distribution of sounds in phonetic form, and is distinguished from a separate morphophonological representation, where relations between words containing the same morpheme are considered. Thus, German *Bund* [bʊnt] would have the phonemic representation /bʊnt/ and the morphophonemic representation //bʊnd//. The admittance of a morphophonological level of representation raises the question of whether this representation should be considered as the underlying representation of words, and accorded status as psychologically real. A phonemic theory with no morphophonological level must resort to an explicit listing of the allomorphs as multiple URs for alternating morphemes, while in a theory with distinct levels of morphophonological and phonemic representations, allomorphs can be defined by the mapping between the two. The morphophonemic analysis is illustrated here with the English regular plural suffix. This morpheme can be said to possess three allomorphs in complementary distribution: /-z/, /-s/, and /-əz/. (In a Prague School analysis, it would have the allomorph /-Z/ after an obstruent, where there is no contrast between /s/ and /z/, as in *cats*, *dogs*, and the allomorph /-z/ after a sonorant, as in *boys*, *hens*, where it contrasts with /s/, cf. *voice*, *hence*). Since the distribution of the allomorphs is phonologically conditioned (see CHAPTER 99: PHONOLOGICALLY CONDITIONED ALLOMORPH SELECTION), and furthermore, essentially the same alternation is found with other suffixes such as the genitive and the regular past tense, one possibility is to choose a single underlying morphophonemic representation for each suffix, from which (phonemic and) surface forms could be derived by the application of general rules. The morphophonemic analysis is summarized in (2), in contrast to a phonemic analysis with a listing of allomorphs. Note that the analyses shown here are offered as concrete examples of the phonemic and morphophonemic approaches, and exist alongside other possible analyses of the specification of phonemic or morphophonemic form.

(2) *The English plural suffix in "simple" phonemic, Prague School phonemic, and morphophonemic analyses*

	"simple" phonemic	Prague School phonemic	morpho-phonemic
morphophonemic level:	—	—	//-z// (=UR) *hens*, *cats*, *dogs*, *kisses*
phonemic level:	/-z/ *hens*, *dogs* /-s/ *cats* /-əz/ *kisses* (=UR)	/-z/ *hens* /-Z/ *cats*, *dogs* /-əz/ *kisses* (=UR)	/-z/ *hens*, *dogs* /-s/ *cats* /-əz/ *kisses*

Relevant to our focus here on URs, the critical distinction between the phonemic and morphophonemic analyses illustrated in (2) is whether there is a unique representation specifying the phonological form of all surface realizations of the morpheme (the morphophonemic analysis), or whether each allomorph has an independent phonological representation (the phonemic analyses). The morphophonemic solution is also adopted in Generative Phonology, the theory that supplanted structuralism as the dominant school of American phonology, but with the important difference that the Generative Phonology model of grammar bypasses the "classical" phonemic level.

4 Underlying representations in Generative Phonology

In modern practice the term "underlying representation" (UR) has become associated with the underlying phonological representations of Chomsky and Halle's Generative Phonology, the major development in phonological theory following Bloomfield and his successors in American structuralism. As Chomsky and Halle (1968: 11) explain, their phonological representations are essentially equivalent to the morphophonemic representations of American structuralist phonology. They further make clear that they, however, prefer not to use the term *morphophonemic representation*, because this term seems to imply the existence of a different, *phonemic* level, which they do not believe to be necessary or useful as a level or representation.[4]

Chomsky and Halle's adoption of the morphophonemic level as input for the operation of phonological rules is mostly justified in terms of Chomsky's overall conception of grammar, where the phonology operates on the output of syntactic structures. Since the morphemes that compose a word may appear under different syntactic nodes, morphemes, not words, must be the units of lexical encoding. To use their example, the syntax provides sequences such as $[[sing]_V\ past]_V$ and $[[mend]\ past]_V$, which, after the operation of readjustment rules, become, respectively, the underlying phonological representations $[s*ng]_V$ and $[[mend]_V\ d]_V$ (where * represents the addition to the feature specification of *i* of a new feature "indicating that it is subject to a later phonological rule which, among other things, happens to convert *i* to *æ*"; 1968: 11).

In Chomsky and Halle's framework the units in URs contain segments which are further decomposed into phonological distinctive features, including morphological and syntactic juncture features, and in some instances, such as the examples discussed above, specific diacritic features. URs are mapped onto surface forms through the application of phonological (transformational) rules. These rules apply in a linear order, and the output of a rule yields an *intermediate* form that is the input for subsequent rules, until the final ordered rule applies to yield the surface form.

[4] In denying the status of a distinct level of phonemic representation, Chomsky and Halle were essentially in agreement with Bloomfield (1933), as noted by Koerner (2003). Chomsky and Halle's rejection of structuralism, and phonemic analysis in particular, is directed at the taxonomic phonemic analysis of Twaddell, Bloch, and other post-Bloomfield structuralists (Odden 2005: ch. 3, supplement).

4.1 The criterion of maximizing grammatical generalization

The URs of Generative Phonology, like the phonemic representations of structuralist theories, abstract away from the detail of phonetic form. There is no explicit limit on the degree to which the UR diverges from the phonetic form, and the UR of a given morpheme is not constrained to be identical or even similar to the surface form of any of its allomorphs. For example, Kenstowicz and Kisseberth (1979: 204) propose an analysis of Russian vowel alternations in which the noun "head" is assigned the UR /golov/ 'head', with two full vowels. These vowels never occur simultaneously in the surface form of any word containing this root morpheme, but each occurs in stressed position in different words: ['goləvu] (ACC SG) and [gʌ'lof] (GEN PL).[5] The full vowels in the UR surface intact only in the presence of stress, which is assigned by morphophonological rules, and are otherwise transformed by rule into the reduced vowels [ə ʌ] in unstressed syllables.

URs specify lexically contrastive features (see CHAPTER 17: DISTINCTIVE FEATURES), and leave out any feature that is predictable from the phonological content (including juncture features), but the criterion of contrast is not the sole basis for determining URs in Generative Phonology. Another important criterion is maximizing grammatical generalization. The UR is the form that provides an optimal mapping to *all* the observed surface forms of the morpheme, maximizing the function of phonological rules in specifying predictable information, and in expressing regularities in the distribution of sounds in the language overall.

For example, consider the representation of nasal consonants in a language like Catalan (Herrick 2002; see also Bonet and Lloret 1998: 127–155; Wheeler 2005: 166–219). In certain phrasal contexts, the alveolar nasal /n/ assimilates in place of articulation to a following consonant, as in (3a). The rule of Nasal Assimilation (4), formulated using the notation of Chomsky and Halle (1968), operates on word-final /n/ to change the place of articulation feature in the appropriate contexts. There is a similar pattern of homorganicity in NC clusters that can be observed within words, shown in (3b), i.e. [n] is never found in heterorganic clusters morpheme-internally. These word-internal clusters do not participate in any morphophonological alternations involving nasal place of articulation, but allowing the rule of Nasal Assimilation to apply word-internally to /nC/ sequences offers the maximal generalization, permitting URs like /kanp-ɛt/ 'little field' to be mapped onto surface representations with homorganic NC clusters like [kamp-ɛt]. Under this account, the underlying structure /. . . np . . ./ may be posited even in the absence of any direct evidence for that structure from alternations in surface form, e.g. when the rule system operates to transform the underlying structure in every surface instance.

[5] This also applies to the vowels in the English example *atom*, *atomic*, mentioned in §3.

(3) *Catalan nasal assimilation with* /n/

a.	*son*	[n]	'they are'
	son amics	[n]	'they are friends'
	son pocs	[mp]	'they are few'
	son feliços	[mf]	'they are happy'
	son dos	[n̪d̪]	'there are two'
	son rics	[nr]	'they are rich'
	son germans	[nʲʒ]	'they are brothers'
	son lliures	[nʲʎ]	'they are free'
	son grans	[ŋg]	'they are big'
b.	*campet*	[mp]	'field (DIM)'
	tombet	[mb]	'walk, stroll (DIM)'
	puntet	[n̪t̪]	'point (DIM)'
	banquet	[ŋk]	'bank (DIM)'

(4) *Catalan nasal place assimilation*

$$\begin{bmatrix} +\text{nasal} \\ +\text{coronal} \\ +\text{anterior} \end{bmatrix} \rightarrow [\alpha\text{place}] \; / \; \_\_ \; \# \; [-\text{syllabic}, \alpha\text{place}]$$

4.2 *Underspecification in underlying representation*

An alternative analysis of the Catalan data that avoids positing /n/ as the UR in monomorphemic NC clusters is to allow the nasal consonant to be underspecified for place features in UR. Underspecification in UR was proposed by Kiparsky in an unpublished (1981) manuscript on vowel harmony, and further developed in Kiparsky (1982), Archangeli (1984), Steriade (1987), and Pulleyblank (1988), among others (see Steriade 1995 and CHAPTER 7: FEATURE SPECIFICATION AND UNDERSPECIFICATION for an overview). The proposal is an elaboration of a basic tenet of Generative Phonology as put forth by Chomsky and Halle (1968), namely that URs are devoid of all predictable phonological information (which as noted above is also a core principle of phonemic representation in most phonemic theories). For Chomsky and Halle, segments are specified as bundles of distinctive features, and thus any non-contrastive feature, such as aspiration on voiceless plosives in American English, is omitted from UR. Taking this idea one step further, features that do not function to distinguish contrastive sounds may also be omitted from those contexts in UR, in what is termed *Contrastive Underspecification* (Steriade 1987). Notice that the solutions adopted for underlying representations in generative analysis with underspecification can be very similar or identical to Prague School representations incorporating archiphonemes. This will be the case when features are left underspecified only in contexts of neutralization and the features that are left unspecified are those that in other contexts serve to distinguish two or more segments, as in Catalan *campet* /kaNpɛt/ 'little field', *puntet* /puNtɛt/ 'little point'. A more extreme version of underspecification theory, termed *Radical Underspecification*, holds that for every binary distinctive feature, only one value (the *marked* value) is specified in UR, while the opposite value (the *unmarked* value) is filled in during the course of derivation by either context-sensitive or default phonological rules (Kiparsky 1985; Archangeli 1988).

Applied to Catalan, the principle of contrastive specification in UR means that the place of articulation feature will *not* be specified for nasals in NC clusters, where it is predictable from the following C even though in other contexts, where place features cannot be predicted, they are obligatorily included in UR. This analysis would be identical to a Prague School analysis. In Radical Underspecification analysis, on the other hand, one of the nasals may be left unspecified for place even in contexts where place distinctions are not neutralized, such as word-finally before pause or a vowel. Thus, *són* 'they are' would be represented as /soN/ in Radical Underspecification models even though in this context there is a contrast with the bilabial nasal of *som* /som/ 'we are'. An advantage of the Radical Underspecification approach, in which /n/ is systematically unspecified for place, as /N/, is that its representation accounts for why it is only /n/ that undergoes (major) place assimilation. Nasals with marked place features can occur in heterorganic clusters, e.g. *som dos* 'we are two', *a*[ɲ] *feliç* 'happy year'.

Needless to say, the adoption of underspecification of any sort renders URs more abstract. At the extreme, a segment may lack all distinctive feature content, being defined in UR with no more than a bare syllable position. For example, featureless vowels have been proposed by Choi (1995) for the analysis of Marshallese, and for the analysis of schwa (e.g. Anderson 1982; see also CHAPTER 26: SCHWA).[6]

With this development of underspecification in Generative Phonology in the 1980s, we have reached a zenith with respect to phonological theories with abstract and minimally specified URs. In §7 and §8 we return to consider subsequent developments in phonological theory, which pull URs in the opposite direction, away from abstractness and toward full specification.

4.3 URs and novel word formation

Some evidence in support of a theory that posits URs as a means to maximize grammatical generalization comes from observations about novel word formation (Kenstowicz and Kisseberth 1979: 26ff.). Consider for example the analysis of the English plural in terms of URs (as in (2) above). By positing the underlying form of the plural suffix as /-z/, with phonological rules mapping this UR to its surface reflexes in [-z], [-s], and [-əz], we have a ready account of the behavior of native speakers in forming novel plural words. As shown by Berko (1958), even young children show a preference for novel plurals that conform to familiar lexical patterns (e.g. the plural of *wug* is given with [-z]), which is consistent with the application of a general phonological rule to a common UR for the plural suffix.

The productivity of phonological patterns to novel words may be handled in a theory without URs by explicitly listing each allomorph in the lexicon along with its conditioning environment. Mechanisms of analogical extension can then select the correct allomorph for a novel word form based on its similarity to an existing word form. But, as discussed by Kenstowicz and Kisseberth (1979: 29ff.), the lexical listing alternative is not available for productive phonological rules that

[6] The featureless vowel lacks phonological place features, acquiring place specification only in phonetic implementation. Manner features are typically non-contrastive for vowels, and the major class features that distinguish vowels from consonants can be predicted on the basis of a minimal syllable structure that encodes the vowel as a syllable nucleus. Alternatively, syllable structure itself can be omitted from UR if the vowel is specified for the major class features [–consonantal, +syllabic].

are conditioned by phrasal context, as in the case of Chimwiini vowel length. More recently, Albright and Hayes (2003) present experimental evidence against an account of novel word formation that draws only on analogical extension of existing lexical patterns, based on data from novel word formation in English. They propose that English speakers' ratings of novel past tense forms reflect the operation of rules learned by induction over lexical patterns, but only if rules are constrained to encode phonological structural similarities between lexical items. However, we note that although Albright and Hayes argue for phonological rules as the mechanism for expressing phonological patterns over word forms, their analysis does not require abstract URs and does not give absolute priority to maximizing phonological generalization. Rather, they advocate a model of grammar that allows multiple rules governing morphophonological alternations that are formulated at varying degrees of specificity, reflecting "islands" of morphophonological regularity in the lexicon.

5 Indeterminacy in morphophonemic representations

In a framework with morphophonemic URs, including Generative Phonology in addition to some earlier American structuralist approaches, the problem of determining the most appropriate or optimal UR is even greater than in a simple phonemic theory that lacks a morphophonemic representation. Some issues that arise relate to: (a) the choice of UR when a morpheme has different allomorphs, (b) constraints regarding how abstract URs may be, and (c) determining which words are related.

5.1 Indeterminacy in UR selection

When we have distinct allomorphs of a morpheme, the choice of UR is sometimes less than obvious. Even in the relatively simple case of allomorphy in the English plural and other inflectional suffixes, there is a surprising variety of possible analyses, many of which have been explicitly proposed (see Zwicky 1975; Kenstowicz and Kisseberth 1979: 181; CHAPTER 99: PHONOLOGICALLY CONDITIONED ALLOMORPH SELECTION). For instance, different generative phonologists have proposed analyses where the UR of the plural suffix in English is /-z/, /s/, or /-ɪz/. In Spanish, the plural is generally formed adding /-s/ to stems ending in a vowel, as in *casa*, *casas* 'house, houses', and adding /-es/ to stems ending in a consonant, as in *amor*, *amores* 'love, loves'. Whereas generative phonologists appear to agree in taking /-s/ as the UR of the suffix, there has been much debate on the relative merits of an epenthesis analysis, where *amores* would be derived from /amoɾ+s/ by a rule of vowel insertion (Saltarelli 1970), and a deletion analysis, where all consonant-final stems are provided with a final vowel in their UR, which is deleted in word-final position by rule (Foley 1967; Harris 1969), so that *amor* is /amoɾe/ and *amores* is /amoɾe+s/. In principle, nothing would rule out a third analysis where the UR of the plural suffix is /-es/, with deletion of the suffix-initial vowel in *casas* /kasa+es/.

There are few explicitly stated principles governing the analysis of URs. Deciding on a UR can require careful phonological argumentation, taking many kinds of facts into account and, as we see, different phonologists may come up

with different solutions. It remains unclear what principles of Universal Grammar guide the language learner to a unique correct analysis in indeterminate cases such as these. Note that the issue of choosing the correct UR is especially acute in Generative Phonology, where, barring suppletion, all allomorphs of a given morpheme *must* derive from a unique underlying phonological representation. A theory that does not treat morphophonemic URs as mental constructs has the option of handling alternations of this type simply by lexical listing of each alternant.

5.2 *Abstractness in underlying representations*

The problems in the selection of UR are complicated by the possibility of having indeterminately abstract URs. URs assume a certain degree of abstraction just for adopting phonemic (i.e. phonetically underspecified) representations. When we identify a phoneme /t/ in English which is realized as aspirated [t^h], unaspirated [t], glottalized [$t^?$], flap [ɾ], or glottal stop [ʔ] in different contexts or instances, we are proposing an invariant abstract phonological unit underlying quite different phonetic realizations. But the issue of abstractness and its limits are even more vivid in Generative Phonology precisely because this theory takes the strong position that the relevant units of lexical encoding are morphemes. Since morphemes may appear in quite different shapes in different words, the URs of Generative Phonology can be considerably more abstract than the phonemic representations of words. Again using Chomsky and Halle's example for this point, the underlying representation of *telegraph* must be one from which the surface phonetic representation of *telegraph*, *telegraphic*, and *telegraphy* can be derived. They thus choose +tele+græf+. Elsewhere in the same work, they propose URs that differ quite radically from the surface form of words. Some of the early generative work by other authors also includes very abstract representations. We will consider a couple of examples below, in connection with the issue of word-relatedness.

5.2.1 *Constraining abstractness: The Alternation Condition*

A reaction to the abstractness of URs in Generative Phonology is found in the work of Kiparsky (1968), whose Alternation Condition is nevertheless too restrictive for some scholars (e.g. Kenstowicz and Kisseberth 1979; Kenstowicz 1994; Odden 2005). Hooper's (1976) True Generalization Condition amounts to a wholesale rejection of the theory behind morphophonemic URs, since the condition essentially limits the scope of phonological rules to phonotactics. Whereas in more recent times there has been a tendency to disfavor very abstract morphophonological URs, the fact is that the issue has not been explicitly resolved so much as sidestepped in contemporary work in Generative Phonology.

Because of its historiographic importance, we will briefly review Kiparsky's (1968) proposal here. In formulating the Alternation Condition, Kiparsky's focus is on analyses within the framework of Generative Phonology that posit underlying forms that contain elements that never surface as such, but which serve to condition the application of a phonological rule whose output could not otherwise be predicted on the basis of the surface forms that actually do appear. The Alternation Condition prohibits analyses in which all phonological derivations of an underlying form (a morpheme) result in the neutralization of a contrastive element, termed an "absolute" neutralization. The offending analyses posit different underlying representations for what appears in surface form as the same segment, in order

to account for differences in phonological behavior conditioned by that segment, in different words. Generally these are cases where two historically distinct phonemes have merged. We will briefly consider one of the examples treated by Kiparsky.

A synchronic statement about Sanskrit is that velars palatalize before /i/ and before some, but not all, instances of /a/. The historical explanation for this state of affairs is that palatalization took place before the front vowels /i e/, but subsequently in the diachronic development of the language, all non-high /e a o/ vowels merged in /a/ (Hock 1991: 149; see also CHAPTER 71: PALATALIZATION).

(5) *Sanskrit velar palatalization*

*gegome	>	/ʤaga:ma/	'went'
*giwo	>	/ʤi:va/	'alive'
*penke	>	/paɲʧa/	'five'

A possible synchronic analysis in a Generative Phonology approach would postulate underlying /e/ as distinct from /a/ and formulate the rule as palatalization of /k g/ before front vowels. This would be followed by another rule converting all instances of /e/ into /a/: /ke/ → /ʧe/ → [ʧa]. This derivation involves absolute neutralization, since underlying /e/ never surfaces as such in the morphemes that condition palatalization. In every instance it is neutralized with /a/ after the application of the palatalization rule. The /e/ vowel is posited in the underlying representations only to make the palatalization rule appear to be regular. This exemplifies the diacritic use of phonological content that Kiparsky's Alternation Condition is intended to disallow.

As mentioned, some generative phonologists argued that Kiparsky's constraint is too restrictive. For instance, Kenstowicz (1994: 113), following Chomsky and Halle (1968), claims that the alternation between [aj] and [ɪ] in words like *divine* and *divinity* derives from a common source in "underlying long [i:]." He points out that the putative underlying vowel does not surface as such in any surface realization of the root morpheme. Rather, the underlying vowel /i:/ is either diphthongized as in *divine* or undergoes shortening as in *divinity*. Kenstowicz reasons that the merits of the phonological analysis of Vowel Shift in these examples (and extending to certain other alternations between long and short vowels) favor rejecting the Alternation Condition. For Kenstowicz, the critical criterion for judging the validity of an abstract UR is whether positing such a form results in a simpler grammar (i.e. one with fewer and less complex rules), and achieves broader generalization in characterizing the sound patterns across the lexicon. These criteria require an evaluation method for measuring complexity and generalization, which is in itself problematic, but do not require any constraints on abstractness in UR per se, or methods for measuring the degree of abstractness in UR.

5.2.2 Abstract URs and opacity

A sound pattern that arises due to a phonotactic constraint or through morphophonological alternation is said to be *opaque* if its conditioning environment is not present in surface form, but can be identified in a UR. Kenstowicz and Kisseberth (1979) show that certain opaque patterns can be successfully and succinctly characterized in Generative Phonological analyses that involve abstract URs set up to

contain appropriate triggering conditions for the opaque sound pattern, only to have the triggering elements subsequently modified or eliminated by rules that apply later in the derivation. An example is the analysis of Palestinian Arabic word stress (Kenstowicz and Kisseberth 1979: 229–231; see also CHAPTER 124: WORD STRESS IN ARABIC), which is described by the following rule:

(6) *Stress in Palestinian Arabic*

a. Stress the final syllable if it contains a long vowel or ends in a consonant cluster: [ka'maːn] 'also', [dara'stiː] 'you (FEM) studied it', [da'rast] 'I studied'; or else:
b. Stress the penultimate if heavy: [da'rasti] 'you (FEM) studied', [ba'tˁaːtˁa] 'potato'; or else:
c. Stress the antepenult: [da'rasatu] 'he studied it'.

There are two sets of surface exceptions to the pattern defined by these rules. In one group of words stress is antepenultimate even though the penultimate is heavy. A second group of exceptions have final stress even though the last syllable does not have a long vowel and does not end in a consonant cluster:

(7) *Surface exceptions to the stress rules*

a.	['btudursi]	'you (FEM) study'
	['simismu]	'his sesame seeds'
	['zuʔurtu]	'his bees'
b.	[bji'trin]	'string (3MASC)'
	[bji'truʤ]	'shake (3MASC)'
	[bji'tam]	'persist (3MASC)'

Kenstowicz and Kisserberth argue that all these exceptions can be explained if the stress rules take morphophonemic URs into account. The set of words in (7a) have roots whose segments appear in a different order in contexts when they are not followed by a vowel-initial suffix; e.g. ['btudrus] 'you (MASC) study'. The stress assignment in these words would be regular if stress were assigned to the URs before a systematic rule of metathesis: /b-tudrus-i/ stress assignment → /'btudrusi/ metathesis → /'btudursi/. As for the examples in (7b), other forms in the paradigms of these words show that the UR of the stem ends in a geminate, e.g. [bi'trinni] 'ring (2SG FEM)'. The surface forms in (7b) would be derived by a totally general rule that simplifies geminates at the end of a word, applying after stress assignment.

In a theory that eschewed abstract URs in favor of representations that are transparent to surface phonetic form, the facts in (7) would be treated as true exceptions to the otherwise systematic, syllable-dependent distribution of stress in Palestinian Arabic. The possibility of the systematic analysis of opaque systems, as above, makes a compelling case for allowing URs to contain elements that don't survive in surface forms. But the question arises whether the problem justifies the solution. Are opaque sound patterns sufficiently robust and productive to warrant an analysis in terms of regular grammatical rules or constraints? Or do speakers of the language treat such patterns as localized exceptions, in which case an analysis in terms of lexical exceptions to a regular pattern would

be more appropriate? Productivity may be implemented as analogical patterns without the need for abstract, morphophonemic URs (see Cole and Hualde 1998 for discussion).

5.3 Indeterminacy in word relatedness

In order to provide consistent underlying representations at the morpheme level, a phonologist (and a language learner) should be able to determine in some principled way which words contain the same morpheme. It should be obvious, however, that, except for inflectional paradigms – and even there we may have suppletion – deciding which sets of words are related in terms of underlying phonological representations becomes very much a subjective decision of the analyst in many cases. Phonological theory has yet to offer a principled way to decide these issues.

Two examples suffice to illustrate the problem in determining morphophonological relatedness. As an example of early work in the Generative Phonology framework, Harris (1969: 169) considers that the Spanish noun *eje* /'exe/ 'axle, axis' and the adjective *axial* /ak'sial/ 'axial' are related – as they surely are from a historical point of view – and proposes an underlying form /akse/ for ['exe]. Similarly, he analyzes *leche* ['leʧe] 'milk' as /'lakte/ to capture its relationship with the adjective *láctico* 'lactic'. More than a decade later, Lightner (1983: 205), after arguing that the root of English *long* and *length* should be given a single UR in synchronic analysis, suggests that, since the adjective *dolichocephalic* 'long-headed' is surely also related to these other words, a better UR for the root morpheme may be /dl-/, followed by a suffix in /dl-nk^{h}/ *long*. An exceptionless phonological rule of English would simplify the initial group /dl/. The problem for this method lies in deciding how much derivation is appropriate in a synchronic grammar – are there any practical limits that constrain the language learner in establishing a shared component of UR for a pair of words? Adding the possibility of diacritic features and abstract URs only further broadens the range of possible analysis. We are faced with many plausible or possible analyses, and few if any criteria for deciding which one is correct. Much seems to depend on which sets of words the analyst is willing to consider as containing the same morpheme. Odden (2005: 273) explicitly addresses this concern, concluding that "[t]he question of how to judge formal word-relatedness remains controversial to this day, and with it, many issues pertaining to phonological abstractness."

An independent but related problem, given claims of psychological realism, is that the theory must allow for constant updating of underlying representations as new words are learned. Chomsky and Halle (1968: 233) propose that in order to account for both the lack of vowel laxing and the presence of the affricate [ʧ] instead of [ʃ] in *righteous* (from *right*), the UR of the root should be /rixt/. That is, the UR of *right* is altered after the learner encounters the word *righteous*. Likewise, the Spanish-speaking child may need to wait until her school years, when she may learn the word *láctico*, to determine the ultimate underlying representation of the word *leche* 'milk' and may have to wait until late adulthood to learn the word *axial*, which would trigger a change in UR from /exe/ to /akse/ for the word *eje* 'axle' that she learned in childhood (see also Janda 2003: 419). In the analytic framework of Generative Phonology, the consequences of even small changes in the UR of established words could have very large ramifications for

the grammar as a whole, with ripple effects possibly extending throughout the rule system. We are not aware of any work that explores this prediction, testing for effects of large-scale grammatical restructuring in late stages of language acquisition or in adulthood.

On the positive side, morphophonological URs can be a useful mechanism for capturing speakers' intuitions regarding word-relatedness. For instance, speakers may have the intuition that two words that are phonetically identical (homophones) are different if they show different behavior under suffixation. This knowledge can be represented in morphophonological URs.

5.4 Summary

In this section we have seen that the validity of a phonological theory that posits morphophonological forms as URs depends on a successful and constrained method for determining URs, and that such a process will necessarily involve the determination of word relatedness. Indeterminacy about the level of abstractness in URs, together with indeterminacy in establishing which words are related through a common morpheme in UR, can render the analysis opaque, which leaves us to wonder how the phonologist can arrive at the correct analysis, or beyond that, how language learners converge on a common, correct analysis of the URs of their target language. Despite serious efforts to resolve some of these issues in the years since the publication of Chomsky and Halle's seminal work (1968), notably in Kiparsky's (1968) work on constraining abstractness, and his later work on Lexical Phonology (1985), the problem of the indeterminacy of URs remains largely unresolved today.

6 Underlying representations in Optimality Theory

In Generative Phonology, as proposed by Chomsky and Halle (1968), the phonological rules that map URs to surface forms in successive steps are "input-oriented"; they apply only if the necessary conditioning environments are present in the representation that is the input to the rule (i.e. the underlying or intermediate form), and are not sensitive to properties of the output form. Optimality Theory (Prince and Smolensky 1993) is a development from Generative Phonology in which input-oriented rules are eliminated in favor of constraints on surface form. Optimality Theory maintains the morphophonological URs of Generative Phonology, but in place of a stepwise derivation that maps URs onto surface forms through the application of ordered rules, Optimality Theory invokes static constraints that evaluate surface forms for their adherence to phonotactic constraints and for the "faithful" correspondence between the UR and a candidate surface realization of that form.

A principle of Optimality Theory is the claim that URs are entirely unconstrained ("Richness of the Base"): any structure that can be defined through the legal combination of phonological elements is a potential UR in any language. Like its predecessors in Generative Phonology, Optimality Theory maintains the claim of a unique UR for each morpheme, and many analyses employ the same kinds of morphophonological URs as in rule-based Generative Phonology. Optimality Theory inherits many of the concerns discussed above related to abstractness of

representations and indeterminacy in identifying morphological relatedness. To constrain the process of selecting a UR from the vast set of possible forms allowed under Richness of the Base, Optimality Theory introduces a principle of Lexicon Optimization, which aids in the specification of a UR by forcing the selection of the underlying representation that gives the most harmonic mapping between UR and surface form, which is calculated by comparing the number of constraint violations for equally ranked constraints (see McCarthy 2002: 23, 77).

The architecture of Optimality Theory, with constraints that evaluate the identity between two phonological representations, allows for the possibility of eliminating URs altogether, in a purely surface-oriented grammar, as noted by authors such as Burzio (1996). Making no reference to URs, surface phonological patterns can be modeled through constraints that evaluate the identity between distinct surface forms of words under specific morphological conditions (e.g. when two surface forms share the same morpheme, or in the presence of a reduplicating morpheme).

The emphasis on surface constraints as the source of explanation in Optimality Theory has also led to analyses with URs that are phonetically specified, and to the formulation of constraints that refer to non-contrastive phonetic detail. The "surface-oriented" approach of Optimality Theory has invited a greater focus on the phonetic factors that shape phonological systems (as illustrated by many of the papers in Hayes *et al.* 2004), a trend that extends also to Exemplar Phonology and Articulatory Phonology, to which we now turn.

7 Phonetic detail in lexical representations: Exemplar Phonology

The preceding sections document the long history of the notion that the building blocks of speech, i.e. the basic elements of phonological form, are abstractions over detailed phonetic form, but in the period of scholarship that predates Generative Phonology there was substantial disagreement between scholars about the psychological reality of abstract (phonemic or morphophonemic) representations. Thus, while Baudouin de Courtenay and Kruszewski of the Kazan School emphasized the status of phonemes as mental entities, Bloomfield asserted a behaviorist view of the independence of linguistic analysis from any psychological assumptions about the status of linguistic constructs, a position that goes back to Saussure, and was shared by Twaddell (1935), among others (see Anderson 1985 for further discussion of mentalism in the works of these and other phonologists).

The strongest claim for the psychological reality of phonological representations is made in Generative Phonology, where abstract morphophonemic representations are the basis of lexical encoding. URs, which are composed of discrete distinctive feature specifications and, as we have seen, are often highly abstract relative to phonetic form, comprise the representations of spoken language that are stored in long-term memory, and thus they are the units that serve the physical processes of speech production and perception.

This view, which went largely unchallenged for several decades after the seminal papers in Generative Phonology (including Halle 1959 and Chomsky and Halle 1968), has been revisited in recent years. A rapid expansion of research using methods from experimental and computational sciences and corpus linguistics provides converging evidence that phonetic detail is part of the information that

is stored in the long-term memory of words, influencing processes of speech production and perception, and ultimately shaping patterns of sound change (Pierrehumbert 2002). Evidence that phonetic detail influences lexical representation is offered by Bybee (2000, 2001), based on her findings that the incidence of lenition or deletion of word-final /t d/ in English is related to the frequency of occurrence of individual words in everyday language use. High-frequency words are more likely to exhibit lenition or deletion than low-frequency words (see also Bell *et al.* 2003). Bybee argues that small changes in the phonetic realization of a phoneme, however they may be conditioned, are reflected in the phonetically detailed lexical representation, which may be construed as a cluster of exemplars or a specification of the distribution of continuous-valued features in phonetic space. High-frequency words are more frequently "updated"; any contextually driven lenition affecting the most frequent forms will yield an incremental process of phonetic reduction which, over time, and in the appropriate sociolinguistic context, can result in sound change. Even phonetic detail that is not related to linguistic form, such as the phonetic detail that distinguishes one speaker's voice from another, can influence the long-term memory representation of a specific word spoken by that speaker, as shown in work by Goldinger, Pisoni, and their collaborators, among others (e.g. Palmeri *et al.* 1998; Goldinger 2000).

These are only some examples from a growing variety of studies that raise questions about the traditional division between phonetics and phonology (Pierrehumbert *et al.* 2000; see also CHAPTER 89: GRADIENCE AND CATEGORICALITY IN PHONOLOGICAL THEORY and CHAPTER 90: FREQUENCY EFFECTS). The findings are at odds with the assumption that phonetic detail is removed from phonological representation, and are incompatible with theories in which phonetic detail plays no role in phonological representation or in the functioning of rules and constraints of phonological grammar.

The presence of phonetic effects on phonology can be better modeled in exemplar theory, originating in psychological theories of categorization. Whereas in other approaches to phonology, and Generative Phonology in particular, the phonetic detail that arises in speech production derives from an abstract lexical representation, in Exemplar Phonology it is the abstract elements that are formed on the basis of statistical patterning of phonetic detail as experienced by the speaker/hearer (e.g. Pierrehumbert 2001; Johnson 2007; Cole 2009). It follows then that higher-level phonological structures (features, phonemes, syllables, etc.) may differ from word to word, and from speaker to hearer. In Exemplar Phonology there is no single, discrete UR that identifies the sound representation for each word in the language; rather, the mental encoding (i.e. lexical form) consists of a patchwork representation that links together information at different levels of granularity, from abstract category-level information (e.g. specifying the syllable structure of a word) to fine detail (e.g. specifying the range of VOT values of a plosive occurring in the word). And even though exemplar models do not explicitly recognize distinct levels of representation, relationships between words that share morphemes (e.g. *telegraph*, *telegraphy*) can be modeled in Exemplar Phonology without recourse to an explicit, abstract morphophonological form.

The status of abstract elements in phonological representation is still very much a matter of debate in phonology, as researchers continue to investigate the evidence for the role of phonetic detail in shaping phonological systems and influencing speech behavior on one hand, and the evidence for the priority of abstract phonological structures on the other.

8 A non-segment-based theory of UR: Articulatory Phonology

Many theories of phonology refer to phonetic properties as the basis of phonemic (or lexical) contrasts between sounds. Jakobson's distinctive features (Jakobson *et al.* 1952) incorporated both acoustic and articulatory features, while subsequent work in Generative Phonology emphasized the articulatory basis of phonological features, assigning features to hierarchically grouped classes (Clements and Hume 1995). But despite the phonetic attributes associated with phonological features, they are not equated with the actual articulatory or acoustic parameters that specify phonetic form.

As one of the first among contemporary works that integrate phonetic and phonological analysis, Browman and Goldstein (1986) introduced a model of phonology in which the atoms of phonological encoding are articulatory gestures (see also CHAPTER 5: THE ATOMS OF PHONOLOGICAL REPRESENTATIONS). In their theory of Articulatory Phonology, gestures are the low-dimensional features that encode the dynamic actions of the speech articulators in the lexical form of words. Gestures represent the actions of the lips, tongue, and jaw in the formation of constrictions along the length of the vocal tract, and are coordinated in "ensembles." Segments have no direct representation in this model, but may be emergent from stable and recurring gesture ensembles.

The mapping from abstract gestures to their implementation in physical actions of the articulators is achieved with a mathematically explicit mechanical model rather than a formal symbolic grammar. Articulatory gestures differ from the segments and distinctive features of earlier theories in that they have inherent temporal and size dimensions. The phonological and phonetic content of words is represented using a set of gestures whose relative timing is coordinated in a limited number of patterns (e.g. in-phase or anti-phase) (Goldstein *et al.* 2006). These timing patterns result in sequences of gestures that may overlap in time and reduce in magnitude. Familiar phonological phenomena such as assimilation and lenition are some of the phonological effects that are modeled through patterns of gesture overlap and reduction in this approach.

Articulatory Phonology, like Exemplar Phonology, does not recognize explicit, distinct levels of phonological representation, and does not attempt to model morphophonemic alternation beyond cases that have a transparent basis in articulation, such as assimilation to an adjacent speech gesture. At the same time, Articulatory Phonology is distinguished from Exemplar Phonology in its strong claim that phonological encoding is articulatory and not acoustic, and by the characterization of phonological form as a distinct and singular representation, not a cluster of individual instances of spoken words.

9 Conclusion

A recurrent theme throughout the history of phonological theory is that in each language there is a representation of the spoken form of a word that specifies the essential contrastive elements that distinguish that word in its spoken form from all other non-homophonous words in the language. In the preceding pages we

have traced the development of this notion through the European and American theories of phonology over approximately the last century, where we observe an historical progression toward representations that are increasingly abstract relative to the physically experienced spoken word. Not all theories attribute psychological reality to these abstract phonological forms, but since the introduction of Generative Phonology in the 1960s, the focus of phonological theory has been precisely on the matter of representations and grammar as components of the uniquely human cognitive system.

The trend toward increasingly abstract representations has reversed in much of the work in phonology since around 1990, and continuing to the present day. In theories as divergent as Optimality Theory, Exemplar Theory, and Articulatory Phonology, there is an increasing acceptance of the notion that phonetic detail of the sort typically relegated to a phonetic component plays a role in defining the properties of individual phonological systems, and, by extension, partly determines properties of phonological typology across languages. Contemporary theories differ in whether phonetic factors play a role in synchronic grammar, e.g. in some work in Optimality Theory, or only in diachrony as the basis for sound change, as claimed in Evolutionary Phonology (Blevins 2004; see also Hale and Reiss 2000). But both views require a theory where phonetic detail is available to phonological generalization, and a rejection of the strict separation of phonetic and phonological levels.

We observe two factors that have driven the move to abstraction in URs. First is the problem of determining the identity of the phonological units (phonemes) in contexts of neutralization, where there is not a one-to-one mapping between phonetic and phonological units. This concern marked the development of the Prague School phonemic theory with archiphonemes, and was also seen as one motivation for the distinction between morphophonemic and phonemic levels in American structuralist theory. A concern for the mapping between phonetic and phonological form is a factor in contemporary theories, and is a primary motivation for the adoption in Articulatory Phonology of gestural features, which are abstractions over the phonetic variability of different instances of the same word.

A second factor behind the adoption of abstract URs was the treatment of morphological alternations, and the perceived need to provide a common phonological representation for (non-suppletive) allomorphs of the same morpheme. To unify the phonological representation of systematically related allomorphs, structuralist theories and Generative Phonology alike rely on abstract morphophonological representations (though as noted earlier, the current focus in Generative Phonology has shifted away from questions of morphophonological representation and toward the question of the link between phonetics and phonology). The adoption of abstract morphophonological URs in Generative Phonology is necessitated by the adherence to a principle of compactness of phonological grammars. The overriding goal of phonological analysis in classical, rule-based Generative Phonology is to arrive at a set of URs and a set of grammatical rules that maximally express generalizations about phonotactics and alternations. The optimal analysis will be compact, with fewer URs and fewer rules, which are specified with minimum phonological structure, necessitating abstract URs.

Theories that lack morphophonological representations must resort to specifying a distinct phonological form for each allomorph of any given morpheme. This is the case for simple phonemic theory (without a morphophonological level), and

also for some contemporary theories. For instance, in Articulatory Phonology the phonological representation specifies gestures, which are directly mapped onto articulatory actions. Any two words that comprise different gestures must have different phonological representations, including many instances of morphologically related words that contain different allomorphs of the same morpheme, e.g. *cats* and *dogs* in English, which contain different allomorphs of the plural suffix. Articulatory Phonology does not address how in the general case the phonological relationship between allomorphs should be modeled in the mind of the speaker/hearer.

A solution to the problem of how to model the phonological relatedness of morphologically related words while allowing phonetically detailed mental representations is offered in Exemplar Theory. Beckman and Pierrehumbert (2003) argue that words are related to other words through two different kinds of connections: those based on shared meaning (e.g. due to shared morphological content) and those based on shared sound structure (due to shared phonological or phonetic content). The two sets of connections don't have to converge on a common representation; phonological relations are formed over phonetic units, while morphological relations are formed over units that encode structural and semantic information related to morphemes. The mental representation of a word consists, then, of a family of interconnected forms coding different linguistic properties of the word, which Beckman and Pierrehumbert describe in terms of a connectionist network. This model falls within the family of exemplar models in that words are represented in the mind of the speaker/hearer in terms of units of phonetic experience, preserving predictable and idiosyncratic phonetic detail alike. Abstract units such as phonemes are viewed as categories formed over phonetic units (and other kinds of units), and are considered as formal syntactic objects in the overall language system.

The association between the physical experience of spoken language and its mental representation will continue to be the focus of research in phonology, as many questions remain to be answered. What is clear from the treatment of URs in phonological theory over the last century is that a complete account of phonology must model both the phonetic and the morphological relationships between words, based on evidence from a rich variety of languages, and on observations about human behavior related to spoken language.

ACKNOWLEDGMENTS

We are grateful to the anonymous reviewers and to the editors for very useful comments.

REFERENCES

Albright, Adam & Bruce Hayes. 2003. Rules vs. analogy in English past tenses: A computational/experimental study. *Cognition* 90. 119–161.

Anderson, Stephen R. 1982. The analysis of French schwa: Or, how to get something from nothing. *Language* 58. 534–573.

Anderson, Stephen R. 1985. *Phonology in the twentieth century: Theories of rules and theories of representations.* Chicago: University of Chicago Press.

Archangeli, Diana. 1984. Underspecification in Yawelmani phonology and morphology. Ph.D. dissertation, MIT. Published 1988, New York: Garland.

Archangeli, Diana. 1988. Aspects of underspecification theory. *Phonology* 5. 183–207.

Baudouin de Courtenay, Jan. 1871. Some general remarks on linguistics and language. Translated 1972 from Russian in Edward Stankiewicz (ed.) *A Baudouin de Courtenay anthology: The beginnings of structural linguistics*, 49–80. Bloomington: Indiana University Press.

Beckman, Mary E. & Janet B. Pierrehumbert. 2003. Interpreting "phonetic interpretation" over the lexicon. In John Local, Richard Ogden & Rosalind Temple (eds.) *Phonetic interpretation: Papers in laboratory phonology* VI, 13–38. Cambridge: Cambridge University Press.

Bell, Alan, Daniel Jurafsky, Eric Fosler-Lussier, Cynthia Girand, Michelle Gregory & Daniel Gildea. 2003. Effects of disfluencies, predictability, and utterance position on word form variation in English conversation. *Journal of the Acoustical Society of America* 113. 1001–1024.

Berko, Jean. 1958. The child's learning of English morphology. *Word* 14. 150–177.

Blevins, Juliette. 2004. *Evolutionary Phonology: The emergence of sound patterns*. Cambridge: Cambridge University Press.

Bloomfield, Leonard. 1933. *Language.* New York: Holt.

Bloomfield, Leonard. 1939. Menomini morphophonemics. *Travaux du Cercle Linguistique de Prague* 8. 105–115.

Bonet, Eulàlia & Maria-Rosa Lloret. 1998. *Fonologia catalana.* Barcelona: Ariel.

Browman, Catherine P. & Louis Goldstein. 1986. Towards an articulatory phonology. *Phonology Yearbook* 3. 219–252.

Burton-Roberts, Noel, Philip Carr & Gerard J. Docherty (eds.) 2000. *Phonological knowledge: Conceptual and empirical issues*. Oxford: Oxford University Press.

Burzio, Luigi. 1996. Surface constraints versus underlying representations. In Jacques Durand & Bernard Laks (eds.) *Current trends in phonology: Models and methods*, vol. 1, 123–141. Salford: ESRI.

Bybee, Joan. 2000. The phonology of the lexicon: Evidence from lexical diffusion. In Michael Barlow & Suzanne Kemmer (eds.) *Usage-based models of language*, 65–85. Stanford: CSLI.

Bybee, Joan. 2001. *Phonology and language use*. Cambridge: Cambridge University Press.

Choi, John D. 1995. An acoustic-phonetic underspecification account of Marshallese vowel allophony. *Journal of Phonetics* 23. 323–347.

Chomsky, Noam & Morris Halle. 1968. *The sound pattern of English*. New York: Harper & Row.

Clements, G. N. & Elizabeth Hume. 1995. The internal organization of speech sounds. In Goldsmith (1995), 245–306.

Cole, Jennifer. 2009. Emergent feature structures: Harmony systems in exemplar models of phonology. *Language Sciences* 31. 144–160.

Cole, Jennifer & José Ignacio Hualde. 1998. The object of lexical acquisition: A UR-free model. *Papers from the Annual Regional Meeting, Chicago Linguistic Society* 34. 447–458.

Foley, James. 1967. Spanish plural formation. *Language* 43. 486–493.

Goldinger, Stephen D. 2000. The role of perceptual episodes in lexical processing. In Anne Cutler, James M. McQueen & Rian Zondervan (eds.) *Proceedings of SWAP (Spoken Word Access Processes)*, 155–159. Nijmegen: Max Planck Institute for Psycholinguistics.

Goldsmith, John A. (ed.) 1995. *The handbook of phonological theory.* Cambridge, MA & Oxford: Blackwell.

Goldsmith, John A. 2008. Generative phonology in the late 1940s. *Phonology* 25. 37–59.

Goldstein, Louis, Dani Byrd & Elliot L. Saltzman. 2006. The role of vocal tract gestural action units in understanding the evolution of phonology. In Michael A. Arbib (ed.) *Action to language via the mirror neuron system*, 215–249. Cambridge: Cambridge University Press.

Hale, Mark & Charles Reiss. 2000. Phonology as cognition. In Burton-Roberts *et al.* (2000), 161–184.
Hall, Kathleen Currie. 2009. A probabilistic model of phonological relationships from contrast to allophony. Ph.D. dissertation, Ohio State University.
Halle, Morris. 1959. *The sound pattern of Russian: A linguistic and acoustical investigation*. The Hague: Mouton.
Harris, James W. 1969. *Spanish phonology*. Cambridge, MA: MIT Press.
Harris, Zellig S. 1944. Simultaneous components in phonology. *Language* 20. 181–205.
Harris, Zellig S. 1951. *Methods in structural linguistics.* Chicago: University of Chicago Press.
Harris, Zellig S. 1960. *Structural linguistics.* Chicago: University of Chicago Press.
Hayes, Bruce, Robert Kirchner & Donca Steriade (eds.) 2004. *Phonetically based phonology*. Cambridge: Cambridge University Press.
Herrick, Dylan. 2002. Catalan phonology: Cluster simplification and nasal place assimilation. In Caroline Wiltshire & Joaquim Camps (eds.) *Romance phonology and variation*, 69–83. Amsterdam & Philadelphia: John Benjamins.
Hock, Hans Henrich. 1991. *Principles of historical linguistics*. 2nd edn. Berlin & New York: Mouton de Gruyter.
Hooper, Joan B. 1976. *An introduction to natural generative phonology*. New York: Academic Press.
Hualde, José Ignacio. 2004. Quasi-phonemic contrasts in Spanish. *Proceedings of the West Coast Conference on Formal Linguistics* 23. 374–398.
IPA. 1999. *Handbook of the International Phonetic Association: A guide to the use of the International Phonetic Alphabet*. Cambridge: Cambridge University Press.
Jakobson, Roman. 1949. On the identification of phonemic entities. *Travaux du Cercle Linguistique de Copenhague* 5. 205–213.
Jakobson, Roman, C. Gunnar M. Fant & Morris Halle. 1952. *Preliminaries to speech analysis: The distinctive features and their correlates*. Cambridge, MA: MIT Press.
Janda, Richard. 1999. Accounts of phonemic split have been greatly exaggerated – but not enough. In John J. Ohala, Yoko Hasegawa, Manjari Ohala, Daniel Granville & Ashlee Bailey (eds.) *Proceedings of the 14th International Congress of Phonetic Sciences*, 329–333. Berkeley: Department of Linguistics, University of California, Berkeley.
Janda, Richard. 2003. "Phonologization" as the start of dephonetization – or, on sound change and its aftermath: Of extension, generalization, lexicalization, and morphologization. In Brian Joseph & Richard Janda (eds.) *The handbook of historical linguistics*, 401–422. Malden, MA: Blackwell.
Johnson, Keith. 2007. Decisions and mechanisms in exemplar-based phonology. In Maria Josep Solé, Patrice Speeter Beddor & Manjari Ohala (eds.) *Experimental approaches to phonology*, 25–40. Oxford: Oxford University Press.
Jones, Daniel. 1967. *The phoneme: Its nature and use*. Cambridge: Cambridge University Press. 1st edn, 1950. Heffer & Son.
Kenstowicz, Michael. 1994. *Phonology in generative grammar.* Cambridge, MA & Oxford: Blackwell.
Kenstowicz, Michael & Charles W. Kisseberth. 1979. *Generative phonology: Description and theory.* New York: Academic Press.
Kenyon, John S. & Thomas A. Knott. 1953. *A pronouncing dictionary of American English*. 4th edn. Springfield, MA: Merriam.
Kiparsky, Paul. 1968. How abstract is phonology? Distributed by Indiana University Linguistics Club. Reprinted in Paul Kiparsky (1982), *Explanation in phonology*, 119–163. Dordrecht: Foris.
Kiparsky, Paul. 1981. Vowel harmony. Unpublished ms., MIT.
Kiparsky, Paul. 1982. Lexical morphology and phonology. In Linguistic Society of Korea (ed.) *Linguistics in the morning calm*, 3–91. Seoul: Hanshin.
Kiparsky, Paul. 1985. Some consequences of Lexical Phonology. *Phonology Yearbook* 2. 85–138.

Koerner, E. F. K. 2003. Remarks on the origins of morphophonemics in American structuralist linguistics. *Language and Communication* 23. 1–43.

Lass, Roger. 1984. *Phonology: An introduction to basic concepts.* Cambridge: Cambridge University Press.

Lightner, Theodore M. 1983. *Introduction to English derivational morphology*. Amsterdam: John Benjamins.

McCarthy, John J. 2002. *A thematic guide to Optimality Theory*. Cambridge: Cambridge University Press.

Odden, David. 2005. *Introducing phonology*. Cambridge: Cambridge University Press.

Oñederra, Miren Lourdes. 1991. Free ride edo *tella = teila*. In Joseba A. Lakarra & Iñigo Ruiz Arzalluz (eds.) *Memoriae L. Mitxelena Magistri Sacrum*, 625–634. Donostia-San Sebastián: Diputación de Gipuzkoa.

Palmeri, Thomas J., Stephen D. Goldinger & David B. Pisoni. 1998. Episodic encoding of voice attributes and recognition memory for spoken words. *Journal of Experimental Psychology: Learning, Memory and Cognition* 19. 309–328.

Pierrehumbert, Janet B. 2001. Exemplar dynamics: Word frequency, lenition, and contrast. In Joan Bybee & Paul Hopper (eds.) *Frequency and the emergence of linguistic structure*, 137–157. Amsterdam & Philadelphia: John Benjamins.

Pierrehumbert, Janet B. 2002. Word-specific phonetics. In Carlos Gussenhoven & Natasha Warner (eds.) *Laboratory phonology 7*, 101–139. Berlin & New York: Mouton de Gruyter.

Pierrehumbert, Janet B., Mary E. Beckman & D. Robert Ladd. 2000. Conceptual foundations of phonology as a laboratory science. In Burton-Roberts *et al.* (2000), 273–303.

Pike, Kenneth L. 1947. *Phonemics: A technique for reducing languages to writing.* Ann Arbor: University of Michigan.

Prince, Alan & Paul Smolensky. 1993. Optimality Theory: Constraint interaction in generative grammar. Unpublished ms., Rutgers University & University of Colorado, Boulder. Published 2004, Malden, MA & Oxford: Blackwell.

Pulleyblank, Douglas. 1988. Underspecification, the feature hierarchy and Tiv vowels. *Phonology* 5. 299–326.

Saltarelli, Mario. 1970. Spanish plural formation: Apocope or epenthesis? *Language* 46. 89–96.

Saussure, Ferdinand de. 1916. *Cours de linguistique générale.* Lausanne & Paris: Payot.

Steriade, Donca. 1987. Redundant values. *Papers from the Annual Regional Meeting, Chicago Linguistic Society* 23(2). 339–362.

Steriade, Donca. 1995. Underspecification and markedness. In Goldsmith (1995), 114–174.

Taylor, John R. 2006. Where do phonemes come from? A view from the bottom. *International Journal of English Studies* 6. 19–54.

Trubetzkoy, Nikolai S. 1939. *Grundzüge der Phonologie*. Göttingen: van der Hoeck & Ruprecht. Translated 1969 by Christiane A. M. Baltaxe as *Principles of phonology*. Berkeley & Los Angeles: University of California Press.

Twaddell, W. Freeman. 1935. *On defining the phoneme*. Baltimore: Waverly Press. Reprinted in Martin Joos (ed.) 1957. *Readings in linguistics*, 55–80. Washington, DC: American Council of Learned Societies.

Wells, Rulon. 1949. Automatic alternations. *Language* 25. 99–116.

Wheeler, Max W. 2005. *The phonology of Catalan.* Oxford: Oxford University Press.

Zuazo, Koldo. 2010. *Burundako Sakanako euskara: ezaugarriak*. Pamplona & Iruñea: Nafarroako Gobernua.

Zwicky, Arnold M. 1975. Settling on an underlying form: The English inflectional endings. In David Cohen & Jessica R. Wirth (eds.) *Testing linguistic hypotheses*, 598–604. Washington, DC: Hemisphere.