Introductory Phonology

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4 Features

4.1 Introduction to Features: Representations

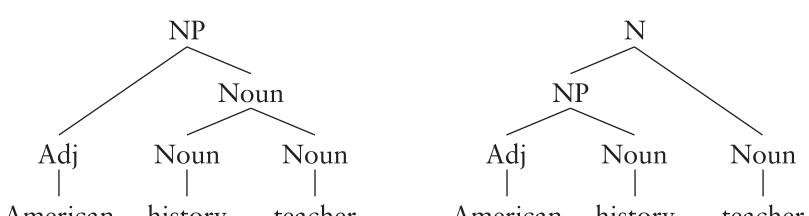
Feature theory is part of a general approach in cognitive science which hypothesizes formal **representations** of mental phenomena. A representation is an abstract formal object that characterizes the essential properties of a mental entity.

To begin with an example, most readers of this book are familiar with the words and music of the song "Happy Birthday to You." The question is: what is it that they know? Or, to put it very literally, what information is embodied in their neurons that distinguishes a knower of "Happy Birthday" from a hypothetical person who is identical in every other respect but does not know the song?

Much of this knowledge must be abstract. People can recognize "Happy Birthday" when it is sung in a novel key, or by an unfamiliar voice, or using a different tempo or form of musical expression. Somehow, they can ignore (or cope in some other way with) inessential traits and attend to the essential ones. The latter include the linguistic text, the (relative) pitch sequences of the notes, the relative note durations, and the musical harmonies that (often tacitly) accompany the tune.

Cognitive science posits that humans possess *mental representations*, that is, formal mental objects depicting the structure of things we know or do. A typical claim is that we are capable of singing "Happy Birthday" because we have (during childhood) internalized a mental representation, fairly abstract in character, that embodies the structure of this song. The process of singing accesses this representation, and uses it to guide behavior: in this case, our own rendition.

Linguistic theory seeks to develop appropriate representations for the mental objects of language. One such representation is the tree diagram, used to represent the structure of phrases:



'history teacher from America' 'teacher of American history'

The utterances above are (at least at faster speaking rates) homophonous; the fact that people can perceive two different meanings when they hear [ə'meɹɨkɨn'hɪstəɹiˌtitʃɚ] is attributed to the possibility of their assigning two distinct representations to the same phonetic string.

Representations are generally stated in a formal notation; this permits us to be more precise about the predictions they make and how rules apply to them.

4.2 Representations in Phonology

Phonology faces the issue of what are the appropriate representations for its mental objects. How are the sounds of speech, and the morphemes and words assembled from them, represented in the mind? This is a difficult issue to settle, and a reliable answer is unlikely to emerge for some time.

However, we do have an important clue, namely the pervasive tendency of phonological rules to apply to **natural classes** (§2.10.4). If phonological rules group segments in particular ways according to the phonetic properties of the segments, it may be a clue that it is precisely the phonetic properties of the segments that constitute their substance.

4.2.1 Feature matrices

Let us suppose, then, that each segment is represented simply as a bundle of features, which collectively define it. The usual formal notation for this is the **feature matrix**. The features are placed in vertical columns enclosed by square brackets, as in the following example:

map ([mæp]):

$$\begin{bmatrix} -\text{syllabic} \\ +\text{sonorant} \\ +\text{stop} \\ +\text{nasal} \\ +\text{labial} \\ +\text{voice} \end{bmatrix} \begin{bmatrix} +\text{syllabic} \\ +\text{sonorant} \\ -\text{stop} \\ -\text{nasal} \\ +\text{low} \\ -\text{back} \\ +\text{front} \\ -\text{round} \end{bmatrix} \begin{bmatrix} -\text{syllabic} \\ -\text{sonorant} \\ +\text{stop} \\ -\text{nasal} \\ +\text{labial} \\ -\text{voice} \end{bmatrix}$$

The columns of the representation are sets of features that define /m/, /æ/, and /p/. Indeed, we may now consider (within the theory we are developing), that symbols such as /m/ and /æ/ are merely convenient abbreviations for the real representations, which, though fully explicit, are an annoyance to write whenever we simply want to identify a segment.

4.2.2 *Applying rules to featural representations*

Given an explicit featural representation for sounds, we can state more precisely what it means for a rule to apply to a form. Here is a simple example. As already noted, it is a rule of English that all vowels are realized as nasalized when they precede nasals; they appear as oral in all other contexts; thus *cam* [kæ̃m] vs. *cab* [kæb]. The Vowel Nasalization rule given on p. 50 is restated below using the features to be covered in this chapter; the feature [+syllabic] in this context abbreviates essentially the class of vowels.

Vowel Nasalization
[+syllabic] → [+nasal] / ___ [+nasal]

The goal here is to apply the rule carefully to the proper name *Pom* (= /pɑm/), deriving [pɑ̃m]. The formal representation for /pɑm/ is as follows.

$$\textit{Pom}: \quad = \quad \left[\begin{array}{l} -\text{syllabic} \\ -\text{sonorant} \\ +\text{stop} \\ -\text{nasal} \\ +\text{labial} \\ -\text{voice} \end{array}\right] \left[\begin{array}{l} +\text{syllabic} \\ +\text{sonorant} \\ -\text{stop} \\ -\text{nasal} \\ +\text{low} \\ +\text{back} \\ -\text{round} \end{array}\right] \left[\begin{array}{l} -\text{syllabic} \\ +\text{sonorant} \\ +\text{stop} \\ +\text{nasal} \\ +\text{labial} \\ +\text{voice} \end{array}\right]$$

In matching up a rule to a form, it is useful to restate the rule in equivalent form so that it maps complete strings to complete strings, without distinguishing target segments from context segments:

Vowel Nasalization (restated)

$$[+\text{syllabic}][+\text{nasal}] \rightarrow \left[\begin{array}{l} +\text{syllabic} \\ +\text{nasal} \end{array}\right] [+\text{nasal}]$$

This rule can be interpreted as "Seek out a feature matrix that includes [+syllabic] directly followed by a feature matrix that includes [+nasal]. Modify the output so that the first of these two matrices will have the value [+nasal]."

The matchup of rule and form goes like this:

$$\textit{Pom}: \quad = \quad \left[\begin{array}{l} -\text{syllabic} \\ -\text{sonorant} \\ +\text{stop} \\ -\text{nasal} \\ +\text{labial} \\ -\text{voice} \end{array}\right] \left[\begin{array}{l} \mathbf{+syllabic} \\ +\text{sonorant} \\ -\text{stop} \\ -\text{nasal} \\ +\text{low} \\ +\text{back} \\ -\text{round} \end{array}\right] \left[\begin{array}{l} -\text{syllabic} \\ +\text{sonorant} \\ +\text{stop} \\ \mathbf{+nasal} \\ +\text{labial} \\ +\text{voice} \end{array}\right]$$

$$\mathbf{[+syllabic]\ [+nasal]} \rightarrow \left[\begin{array}{l} +\text{syllabic} \\ +\text{nasal} \end{array}\right] [+\text{nasal}]$$

and the application of the rule yields this:

$$\textit{Pom}: \quad = \begin{bmatrix} -\text{syllabic} \\ -\text{sonorant} \\ +\text{stop} \\ -\text{nasal} \\ +\text{labial} \\ -\text{voice} \end{bmatrix} \begin{bmatrix} +\text{syllabic} \\ +\text{sonorant} \\ -\text{stop} \\ \mathbf{+nasal} \\ +\text{low} \\ +\text{back} \\ -\text{round} \end{bmatrix} \begin{bmatrix} -\text{syllabic} \\ +\text{sonorant} \\ +\text{stop} \\ +\text{nasal} \\ +\text{labial} \\ +\text{voice} \end{bmatrix}$$

$$[+\text{syllabic}]\ [+\text{nasal}] \rightarrow \begin{bmatrix} +\text{syllabic} \\ \mathbf{+nasal} \end{bmatrix} [+\text{nasal}]$$

The above derivation is explicit regarding the representations and how they are changed. But we also need to state precisely our assumptions about how rules are matched up to forms. First, all features or segments not changed by a rule are assumed to remain the same. Second, when two feature matrices in a rule are adjacent, they can only be matched to two segments which are adjacent. For example, Vowel Nasalization does not apply to *Whitney* /wɪtni/, because the vowel /ɪ/ does not directly precede the nasal consonant /n/; /t/ intervenes. Third, while it is necessary to match everything in the rule, it is not necessary to match everything in the form. Thus, Vowel Nasalization applies to *plump* /plʌmp/ *plump*, because it matches the contiguous string /ʌm/. The additional material /p . . . mp/ is not analyzed by the rule and remains unchanged. Lastly if a rule matches up to more than one location in a form, it applies to all such locations; thus /fændæŋgoʊ/ *fandango* becomes [fæ̃ndæ̃ŋgoʊ], with two applications of Vowel Nasalization.

One reason for formalizing with this degree of care is that it makes it possible for phonologists to reach full agreement about what an analysis predicts. Theory and analysis in phonology can get rather controversial, and the scholarly debates can't get very far if it is not agreed what the prediction of an analysis is. Such disagreement usually results when the analysis is so casually presented that the derivations need human intuition and insight to be carried out.

A fully worked-out theory of rules and representations in phonology involves more than just segments. The later chapters of this book outline a number of other things that must be included: the grouping of segments into morphemes, words, and phrases (chapter 10), syllabification (chapter 13), and suprasegmental information involving stress (chapter 14) and intonation (chapter 15). For now, however, we will assume that a phonological representation consists simply of a sequence of bundles of features.

4.3 A Feature Set: Preliminaries

Many different proposals for phonological feature systems have been made in the research literature. This book presents a fairly "mainstream" feature set, most of whose features were first proposed in Chomsky and Halle's book *The Sound Pattern of English* (1968). Tonal features are not included here but postponed to chapter 15.

4.3.1 The goal of characterizing natural classes

A question that arises at the outset is why not simply use as our features the standard labels of phonetic terminology given by the IPA (chapter 1)? This is what we have been doing so far, with features like [+stop], [+vowel], and so on. The reason for not doing this is that we want our feature system to be able to characterize natural classes, the groupings of sounds that appear in phonological rules (§2.10.4). There are natural classes that are broader than the IPA categories, and we want our feature system to characterize them.

Perhaps the clearest example of such broader categories are those defined by the feature [**sonorant**], which are as follows: stops, fricatives, and affricates are [–sonorant] and all other sounds are [+sonorant]. The following paragraphs give some of the evidence that the feature values [+sonorant] and [–sonorant] define natural classes.

- In Spanish, Japanese, Swahili, and a great number of other languages, it is the class of stops, fricatives, and affricates (that is, the [–sonorant] sounds) that can bear a phonemic contrast for voicing. In [+sonorant] sounds, the value of [voice] is usually predictably [+voice].
- Many languages (e.g. French, Catalan, Russian, Polish, Maltese Arabic) have a rule of Voicing Assimilation, in which a consonant is assigned the same voicing as an immediately following consonant; see p. 133 for an example. Typically, both the set of triggering consonants and those which undergo the rule are restricted to the class of [–sonorant] segments; that is, stops, affricates, and fricatives.
- In many languages (for example German, Dutch, Russian, Polish, and Catalan) there is a rule of Final Devoicing which is similar to the Toba Batak rule on p. 63 but which targets the full class of stops, affricates, and fricatives. It can be stated [–sonorant] → [–voice] / ___ $]_{word}$.[1]

[1] In fact, the Toba Batak rule could just as easily be written [–sonorant] → [–voice] / ___ $]_{word}$ as well. Toba Batak has no final affricates (even voiceless ones), and has no voiced fricatives, so the formulation with [–sonorant] would work.

- In certain tonal languages (Lithuanian, some ancient Greek dialects), syllables ending in consonants can bear contrastive rising and falling tones (chapter 15) just in case the consonant is *not* a stop, affricate, or fricative; that is, it must be [+sonorant].
- The sound [ŋ] is deleted from the Indonesian prefix [məŋ-] just in case the following sound is a consonant other than a stop, affricate or fricative; that is, [–syllabic, +sonorant].

The conclusion drawn is that the class consisting of stops, affricates, and fricatives, and its complement class, should be considered natural classes in phonology, and the feature set should include a feature, [sonorant], that permits them to be characterized as such. The IPA terminology is inadequate as a feature system because it offers no such feature.

Another name for sounds that are [–sonorant] is **obstruent**.

4.3.2 Defining features

In a complete feature theory, the features will be defined not as lists (like {stop, fricative, affricate}) but with phonetic properties, which can be articulatory, acoustic, or both.

For instance, [+sonorant] segments characteristically have greater acoustic energy than [–sonorant] segments, though the cutoff point is difficult to define. At the articulatory level, [–sonorant] segments have a constriction sufficiently narrow to cause a buildup of air pressure in the vocal tract. You can feel this buildup when you articulate sounds slowly and forcefully: [pa], [t͡ʃa], [sa] etc. have it; [ma], [la], [wa] etc. do not.

Below, the features are identified both by their phonological purpose (that is, the way they classify segments), and more concretely by their phonetic correlates.

4.4 Manner Features

4.4.1 The sonority hierarchy

Since the work of Eduard Sievers in the nineteenth century, phonologists have found it useful to arrange the manners of articulation in a hierarchy based loosely on the acoustic sonority (loudness) of sounds; this is called the **Sonority Hierarchy**. The hierarchy is stated in different versions, of which a fairly simple one is the following:

greater sonority ⟵⟶ less sonority

vowels glides liquids nasals obstruents

The natural classes found in phonological rules often consist of some **contiguous set** of manner types drawn from the hierarchy, such as {vowels, glides, liquids} or {liquids, nasals}. On the other hand, noncontiguous sets, like {glides, nasals}, seldom pattern as natural classes.

A simple scheme to capture this pattern is to adopt four features, each of which defines a particular cutoff point along the sonority hierarchy. The feature [sonorant], just defined, forms one such cutoff point; [+sonorant] segments are more sonorous than [–sonorant]. To cover the complete hierarchy, we add three further features: [**syllabic**], [**consonantal**], and [**approximant**]. Along with [sonorant], they divide up the sonority hierarchy as in table 4.1:

Table 4.1 The sonority hierarchy

<table>
<tr><th>Vowels</th><th>Glides</th><th>Liquids</th><th>Nasals</th><th>Obstruents</th></tr>
<tr><td>[+syllabic]</td><td colspan="4">[–syllabic]</td></tr>
<tr><td colspan="2">[–consonantal]</td><td colspan="3">[+consonantal]</td></tr>
<tr><td colspan="3">[+approximant]</td><td colspan="2">[–approximant]</td></tr>
<tr><td colspan="4">[+sonorant]</td><td>[–sonorant]</td></tr>
</table>

The features [consonantal] and [approximant] can be phonetically defined, in principle, with cutoff points along the hierarchy of acoustic sonority, just like [sonorant]; unlike [sonorant] they appear to lack a clear articulatory definition. The case of [syllabic] is slightly different and is discussed below.

In this system, all of the contiguous sets along the hierarchy are expressible as natural classes. For example, we can describe the set of glides, liquids, and nasals with the formula [–syllabic, +sonorant] (the sonorant consonants). A claimed advantage of this system is that noncontiguous groups of manner types, such as {stops, liquids} *cannot* be expressed as natural classes. To the extent that such groups do not occur in phonological rules, the theory is making the right predictions.

4.4.2 Reconstructing the traditional manner categories

With such a system of manner features, it is unnecessary to employ our earlier features [glide] and [liquid], and we will henceforth dispense with them. The reason is that they can be restated by combining more general features; thus "glide," for instance, is [–syllabic, –consonantal]. More generally, the following definitions hold:

vowel	=	[+syllabic] (but see next section for a complication)
glide	=	[−syllabic, −consonantal]
liquid	=	[+consonantal, +approximant]
nasal	=	[−approximant, +sonorant]
obstruent	=	[−sonorant]

4.4.3 Syllabic consonants

The feature [syllabic] must be defined rather differently from the other sonority features. We will assume a definition based on syllabification, discussed in more detail in chapter 13. Every syllable may be said to have a **nucleus**, which is its most sonorous segment. Segments forming the nucleus of a syllable will be classified as [+syllabic], while the remaining segments in the syllables are classified as [−syllabic].

This definition of [syllabic] is necessary because of the occurrence in many languages of **syllabic liquids and nasals**, as in Serbo-Croatian [tr̩g] ‘square’ or the last sound of English (casual speech) *button* [ˈbʌtn̩]. These sounds lack the sonority of vowels, but nevertheless serve as syllable nuclei and are counted as [+syllabic], as shown below.

$$\text{syllabic liquid} = \begin{bmatrix} \text{+syllabic} \\ \text{+consonantal} \\ \text{+approximant} \end{bmatrix} \qquad \text{syllabic nasal} = \begin{bmatrix} \text{+syllabic} \\ \text{−approximant} \\ \text{+sonorant} \end{bmatrix}$$

Syllabic fricatives and stops are quite rare (they occur in Berber languages), but can be defined analogously. As for syllabic glides, they are assumed under this system to be the same thing as vowels; thus “syllabic [j]” is simply a rather strange way of describing the vowel [i], and similarly for other glide–vowel pairs made at the same place of articulation. The IPA symbol [ɚ], “rhotacized schwa,” is often used as an equivalent of “syllabic r,” which in IPA is [ɹ̩].

In general, the higher the sonority of a speech sound, the more likely it is that languages will use it as a [+syllabic] segment. For instance, it would be inconceivable that a language could use only syllabic liquids as its syllable nuclei and have no vowels. Thus, although the feature [syllabic] is logically independent of sonority, it is very closely related.

4.4.4 Sonority sequencing

The Sonority Hierarchy, expressed here with the manner features, has another important role in phonology, that of governing the phonotactics; that is, the legal sequencing of speech sounds (§3.6). It often governs the sequencing of segments within the syllable. In a language which permits clusters of consonants to occur at the margins of syllables, typically the situation will be this: as one proceeds outward from the nucleus towards the edges of the syllable, one encounters segments of progressively decreasing sonority. Here is an example from English:

trance:	[t	ɹ	æ	n	s]
	obstruent	liquid	vowel	nasal	obstruent

This holds true, I suspect, for well over 99 percent of the world's syllables. But there are notable exceptions. Slavic languages and Persian are notable for having some syllables whose segments occur in orders going strongly against the Sonority Hierarchy; for example Russian [rta] 'mouth, gen. sg.', Persian [qæbl] 'before'; both of these words are monosyllabic.

The individual features for sonority defined above play a role in phonological systems. For instance, only [+approximant] consonants may occur after initial stops in English (/l/ [pleɪ] *play*, /ɹ/ [kɹoʊ] *crow*, /w/ [twɪn] *twin*, /j/ [kjut] *cute*). For an example of [syllabic], see §4.2.2 above; for [sonorant], §4.3.1; and for [consonantal], p. 122.

4.4.5 Classifying the stops, affricates, and fricatives

The manner features defined thus far provide no way of distinguishing the stops, fricative, and affricates from each other. We will use two features for this purposes, [**continuant**] and [**delayed release**].

4.4.5.1 [continuant]

A sound is said to be [–continuant] if it involves a full closure in the oral portion of the vocal tract. Thus, stops like [p t k] are [–continuant], as is the glottal stop [ʔ] and affricates like [tʃ] and [ts]. Moreover, nasals like [m n ŋ] also involve a complete oral closure and are thus [–continuant]. Fricatives, liquids, glides, and vowels do not have a complete oral closure and are classified as [+continuant].[2]

It can be seen that [continuant] is not a sonority feature: nasals are more sonorous than fricatives, but they are [–continuant] and fricatives are [+continuant].

The feature [continuant] predicts an affinity between true stops and nasals. This is illustrated by an optional rule found in many dialects of English. Consider the following data, which occur in my own casual speech and seem to be fairly common in the language as a whole:

[2] In some feature systems, the partial closure (midline of vocal tract) of laterals justifies their being classified as [–continuant]; occasionally the very brief closure of taps, flaps, and trills is taken as justification for their being [–continuant]. The data are problematic, and for simplicity we will classify all laterals, taps, flaps, and trills as [+continuant].

Word	**Phonemic**	**Phonetic**
business	/ˈbɪznəs/	[ˈbɪznəs] or [ˈbɪdnəs]
isn't	/ˈɪzn̩t /	[ˈɪzn̩t] or [ˈɪdn̩t]
doesn't	/ˈdʌzn̩t/	[ˈdʌzn̩t] or [ˈdʌdn̩t]

Apparently in these cases the underlying /z/, which is articulated as a fricative, is adjusted so as to take on the stop articulation of the following /n/. That is, articulatorily, /n/ is a kind of stop, even though acoustically it is more sonorous than a true stop. The /z/ assimilates to it in continuancy.

4.4.5.2 [delayed release]

We also need a feature that distinguishes affricates from stops. In the system used here, stops are [–delayed release], and affricates are [+delayed release]. A sound which is [–delayed release] is a stop in the purest sense, being neither affricated nor nasal.

The word "delay" appearing in the name of this feature refers to the period of semi-closure during which frication noise is produced; and the feature can be phonetically defined with the criterion "includes frication noise." Assuming this definition, it would follow that fricatives are [+delayed release] as well. A phonological reason to consider fricatives as [+delayed release] is given below.

4.4.5.3 The natural classes defined by [continuant] and [delayed release]

Under this system, the three-way distinction between fricatives, affricates, and stops is taken to be a three-valued scale, defined in the usual way with two features (table 4.2):

Table 4.2 The features for stops, affricates, and fricatives

Stops	Affricates	Fricatives
[–continuant]		[+continuant]
[–delayed release]	[+delayed release]	

Below are some examples of the natural classes implied by these features.

In Mandarin Chinese, the class of aspirated phonemes (vocal cords abducted; see §4.7.2 for features) is /p^h/, /t^h/, /k^h/, /t͡s^h/, /ʈ͡ʂ^h/, and /t͡ɕ^h/; that is to say, all and only the stops and affricates. No other sounds (including fricatives) may be [+spread glottis] in this language. The stops and affricates together form the natural class [–sonorant, –continuant]. Limitation of aspiration to this class of sounds is common among languages, including English.

Affricates and fricatives: in Kongo, there is an allophonic rule that takes /t/, /d/, and /s/ to [t͡ʃ], [d͡ʒ], and [ʃ] respectively when /i/ follows. The change involves both place features (alveolar becomes palato-alveolar) and manner features. For the manner features, it suffices to assign the value + to the feature [delayed release]. This will turn the stops /t/ and /d/ into affricates as desired. /s/, in the system given here, is already [+delayed release], and a rule that makes it [+delayed release] will "apply" to it harmlessly, imposing the same feature it already had (this is known as **vacuous application**). The rule for Kongo may be formalized as follows:

Kongo Palatalization

$$\begin{bmatrix} +\text{coronal} \\ -\text{sonorant} \end{bmatrix} \rightarrow \begin{bmatrix} +\text{delayed release} \\ -\text{anterior} \\ +\text{distributed} \\ +\text{strident} \end{bmatrix} \; / \; \_\_\_ \; \text{i}$$

For the place features [coronal], [anterior], [distributed], and [strident], see §4.6 below.

Note that a primitive feature like [+affricate] would be of little help in expressing this rule: a rule that assigned the feature [+affricate] would wrongly convert /s/ into *[tʃ]. As before, it appears that a feature system will work better if it includes higher-level abstract categories, in this case the natural class of affricates and fricatives defined by [+delayed release].

4.4.6 Trills and taps

Nothing in the manner features given so far distinguishes the various types of "r"; plausibly trills and taps have their own features, specifically **[+trill]** and **[+tap]**. Flaps (see p. 7) are distinct from taps in IPA terminology; but it appears unnecessary to include a feature [flap] since flaps also differ from taps in place of articulation. Taps are generally [+anterior] (alveolar) and flaps are [–anterior] (retroflex).

4.5 Vowel Features

4.5.1 Basic vowel features

The fundamental phonetic basis for classifying vowels (§1.5) is to specify their *height*, *backness*, and *rounding*. As a first step, we can ask how many phonemic vowel distinctions occur along each of these three dimensions.

4.5.1.1 Backness

Norwegian has a three-way distinction for backness in its high rounded vowels: /y/ (front), /ʉ/ (central), and /u/ (back), as shown by the following minimal triplet: [byː] 'town' has a front vowel, [bʉː] 'shack' has a central vowel, and [buː] 'live' has a back vowel; all three are high and rounded. In order to capture such a three-way distinction, we need the features [**back**] and [**front**], defined in table 4.3.

Table 4.3 Backness in vowels

Front	**Central**	**Back**
[–back]		[+back]
[+front]	[–front]	

Phonologists sometimes try to make do with a simpler system, using the single feature [back] to render a two-way backness distinction. In such an approach, the central vowels are treated as a subspecies of back vowels. The advantage of a three-way system is that it provides a category for central vowels, allowing systems like Norwegian to be described. Moreover, central vowels such as [ɨ] or the (very common) [a] seem to behave phonologically neither like back vowels nor like front;[3] classifying them as [–front, –back] captures this patterning.

4.5.1.2 Height and tenseness

An unusually rich system of height is found in the front vowels of English, where there is a five-way distinction, going from top to bottom: /i/ (*bead*), /ɪ/ (*bid*), /e/ (more precisely, [eɪ]; *bayed*), /ɛ/ *bed*, /æ/ *bad*. The phonology of English suggests a system with three basic heights (high, mid, low), on which is superimposed an additional, finer distinction commonly called [**tense**]. (A synonym for [–tense] is "lax.")

Height	**IPA symbol**	**[high]**	**[low]**	**[tense]**
upper high	[i]	[+high]	[–low]	[+tense]
lower high	[ɪ]	[+high]	[–low]	[–tense]
upper mid	[e]	[–high]	[–low]	[+tense]
lower mid	[ɛ]	[–high]	[–low]	[–tense]
low	[æ]	[–high]	[+low]	

This system deviates from the way we have treated other phonetic continua, with a feature defining each "cutoff point." Yet there is phonological justification for [tense], at least in English and related languages, because it defines a natural class. Among other things, the vowels of English which are [–tense] ([ɪ], [ɛ], [æ], [ʊ], [ʌ], and in British English [ɒ]) cannot end a word or precede another vowel.

[3] For example, [a] doesn't trigger palatalization rules, as front vowels do; true back vowels are most often rounded, but low central vowels only seldom.

The tense and lax vowels also differ phonetically. The lax vowels tend to be shorter and more centralized, and under slow or emphatic speech there are differences of diphthongization: [+tense] vowels diphthongize toward a higher vowel (*bayed* [be͡id]), [–tense] vowels tend to diphthongize with an inserted schwa: *bid* [bɪ͡əd].

It would be easy to extend the system above to six heights by making [tense] relevant to low vowels as well. However, since tenseness distinctions among low vowels are hard to find, and it will be easier to deal with English (the language of many of our examples) with a five-height system, I will use this system for height in this book.

4.5.1.3 Rounding

Rounding is generally believed to be a binary distinction. Although the phonetic degree of rounding on vowels can vary greatly, there is at most a two-way phonological distinction of rounding, expressed as [+round] vs. [–round].

4.5.2 A feature chart for vowels

It is awkward to reduce the IPA vowel chart (p. 14) to a feature system. The chart offers as many as seven contrasting heights (in the central unrounded vowels), whereas the system used here, intended for use in phonology, uses only five.

Table 4.4 represents an attempt to use the IPA vowel symbols to fill the 30 slots defined by the feature system just given. As can be seen, not every slot has a symbol (one would have to use the IPA diacritics to fill these slots), and not every IPA symbol can be fitted into a slot.

Here are the main divergences between this chart and IPA.

- The chart has no place for [ɐ], a symbol standing for a vowel that is central, unrounded, and a bit higher than low. [ɐ] could fit in the chart as [+low, +tense], were we making tenseness distinctions among low vowels.

Table 4.4 Features used for classifying the dorsals

	[+front, –back]		[–front, –back]		[–front, +back]	
	–round	+round	–round	+round	–round	+round
[+high, –low, +tense]	i	y	ɨ	ʉ	ɯ	u
[+high, –low, –tense]	ɪ	ʏ	–	–	–	ʊ
[–high, –low, +tense]	e	ø	ɘ	ɵ	ɤ	o
[–high, –low, –tense]	ɛ	œ	ə	ɞ	ʌ	ɔ
[–high, +low]	æ	ɶ	a	–	ɑ	ɒ

- IPA provides three mid central unrounded vowels: in order of height, [ɘ, ə, ɜ]. Since the feature system here permits only two (and allowing for three seems rather extravagant in any case), we will use [ɘ] for the [+tense] mid central vowel, and [ə] (a more familiar symbol than [ɜ]) for the [–tense] one.
- In IPA, [a] designates the lowest possible front vowel, lower than [æ]. In the five-height system used here, this symbol is deemed unnecessary for purposes of phonology, and [æ] will be used for the lowest front unrounded vowel, following common descriptive practice.
- Following the practice of many linguists, the symbol [a] is used to denote a low central unrounded vowel, filling the gap in the IPA discussed on p. 14.

4.5.3 Other vowel features

Many languages, particularly in sub-Saharan Africa, distinguish vowels with a feature called [**Advanced Tongue Root**], abbreviated [ATR]. This feature is often involved in **vowel harmony** systems – roughly, all the vowels in a particular word must be either [+ATR] or [–ATR]. It is not yet clear whether [Advanced Tongue Root] is to be considered the same feature as [tense]. Occasionally phonologists use [ATR] instead of [tense] in describing English and other European languages.

There are three more features that are often relevant to vowel inventories:

- [**long**]: For instance, Classical Latin had five contrasting long and five contrasting short vowels: /i iː e eː a aː o oː u uː/. This feature applies as well to consonants; long consonants are often also called **geminates**.
- [**nasal**]: This feature is also a feature of consonants, but serves here to distinguish nasalized from non-nasalized vowels.
- [**stress**]: This turns out to be dubious as a vowel feature; we will later (chapter 14) consider the alternative that it is a feature of syllables, and add other features relevant to stress.

4.6 Place Features for Consonants

4.6.1 Major articulator features

A useful starting point for treating consonant place of articulation is to distinguish the consonants according to the **active articulator** that is used in producing them.

[**+labial**]	=	articulated with the lips
[**+coronal**]	=	articulated with the tongue blade and/or tip
[**+dorsal**]	=	articulated with the tongue body

Often a consonant is made with just one articulator, so it would get the value + for one of the features above and – for the others. In so-called **complex segments**, however, two articulators are involved. Thus, a labial-velar like [k͡p] or [w] involves both lips and tongue body, and thus would be [+labial, +dorsal]. Most clicks, such as [!], involve the tongue tip/blade as well as the tongue body, and are classified as [+coronal, +dorsal]. For more complex segments, see §4.6.5 below.

It is also possible for a consonant to involve none of the articulators just mentioned. This is true for glottal consonants, which in this view are [–labial, –coronal, –dorsal]. For the features that distinguish glottal consonants, see §4.7 below.

The view that place of articulation should be classified by the choice of active articulator receives some confirmation from the phonological pattern of languages. For instance, the following example has been taken as evidence that [+coronal] defines a phonologically relevant class of consonants. Consider the ways in which the definite article of Classical Arabic appears before various stems. It shows up as [ʔal] in the context / ___ [b, f, m, k, x, ɣ, q, ħ, ʕ, ʔ, h, w, j]; that is to say, all but dentals, alveolars and palato-alveolars. Before a consonant of the latter three places of articulation, it is pronounced as a copy of the immediately following consonant, hence producing a geminate ([ˠ] is the IPA diacritic for velarization):

[ʔaθ]	/	___ θ	[ʔas]	/	___ s
[ʔað]	/	___ ð	[ʔasˠ]	/	___ sˠ
[ʔaðˠ]	/	___ ðˠ	[ʔaz]	/	___ z
[ʔat]	/	___ t	[ʔazˠ]	/	___ zˠ
[ʔatˠ]	/	___ tˠ	[ʔan]	/	___ n
[ʔad]	/	___ d	[ʔar]	/	___ r
[ʔadˠ]	/	___ dˠ	[ʔaʃ]	/	___ ʃ

The feature [coronal] is needed here to generalize over both alveolar/dental and palato-alveolar places of articulation.

4.6.2 *Features for classifying the coronals*

Coronal consonants are commonly classified using four features: [**anterior**], [**distributed**], [**strident**], and [**lateral**].

4.6.2.1 [anterior]

The word "anterior" means "towards the front." [+anterior] coronals are articulated at the alveolar ridge or further forward. The IPA places of articulation that are [+anterior] are the (inter-)dentals and alveolars. [–anterior] coronals are articulated behind the alveolar ridge; the IPA places of articulation that are [–anterior] are the palato-alveolars and retroflexes.

[anterior] defines natural classes in the process of **sibilant harmony**, found in many languages including Navajo, Chumash, and Kinyarwanda. In sibilant harmony, all stridents in a word are required to agree in anteriority. Sibilant harmony is also a common substitution process in children's speech; when my son was little I observed him saying [ʃuʃi] for *sushi* and [ʃʌnʃaɪn] for *sunshine*.

4.6.2.2 [distributed]

Both [+anterior] and [–anterior] coronals can be made with either the tongue blade (called **laminal** coronals) or tongue tip (**apical** coronals). In this book, the feature [distributed] will designate this distinction, with laminals counted as [+distributed] and apicals counted as [–distributed].

[+distributed]	= blade	= contact is long, measured front to back
[–distributed]	= tip	= contact is short, measured front to back

The basis of the term "distributed" is evidently as follows: when the tongue blade is used, there is more contact between tongue and roof of mouth; thus, the tongue is "well distributed" over the roof of the mouth.

Dentals and palato-alveolars are normally laminal and alveolars and retroflexes are normally apical. Thus as a rule of thumb the IPA places of articulation can ordinarily be described as follows:

Lamino-dentals	[t̪, d̪, θ, ð, n̪]	[+coronal, +anterior, +distributed]
Apico-alveolars	[t, d, s, z, n]	[+coronal, +anterior, –distributed]
Palato-alveolars	[t͡ʃ, d͡ʒ, ʃ, ʒ]	[+coronal, –anterior, +distributed]
Retroflexes	[ʈ, ɖ, ʂ, ʐ, ɳ]	[+coronal, –anterior, –distributed]

For an example in which [distributed] defines natural classes, see p. 179.

4.6.2.3 [strident]

In this book, the [+strident] sounds are the sibilants, such as [s, z, t͡s, d͡z, ʃ, ʒ, t͡ʃ, d͡ʒ]. Only coronal fricatives and affricates can be [+strident]. [+strident] sounds may be defined articulatorily as follows: the airstream is channeled through a groove in the tongue blade and blown at the teeth. Acoustically, [+strident] sounds are louder than nonstrident fricatives or affricates.

The allomorphs of the English plural suffix plainly identify the class of stridents: [əz] appears after /s z ʃ ʒ t͡ʃ d͡ʒ/ (*glasses*, *mazes*, *bushes*, *garages*, *batches*, *judges*), while [z] or [s] appear after all other sounds. If one takes the analytic approach that the underlying form of the plural is /-z/, one can say that English employs schwa insertion to break up clusters of [+strident] sounds. The avoidance of strident clusters is common in languages.

English Schwa Epenthesis
∅ → ə / [+strident] ___ [+strident] $]_{word}$
Insert schwa between two word-final stridents.

In the name of the rule, **epenthesis** denotes rules of insertion. ∅ → X ("zero becomes X") is the usual formalism for insertion rules.

The feature [strident] is used by some phonologists in a broader sense that includes certain non-coronal consonants; for discussion see footnote 5 below.

4.6.2.4 [lateral]

[lateral] distinguishes /l/ from other coronal liquids and [ɬ, ɮ] from other coronal fricatives. In a lateral sound, the tongue is compressed laterally, so that contact at the edges is incomplete. In this state, air can pass laterally around the tongue.[4]

4.6.3 Features used for classifying the labials

In the system used in this book, the features that subdivide the labials are the following:

[round] = articulated by rounding the lips
[labiodental] = articulated by touching the lower lip to the upper teeth

[round] has already been discussed as a vowel feature. [labiodental] is much more marginal, as only a few languages, such as Ewe and California Spanish, have phonemic contrasts (/ɸ/ vs. /f/, /β/ vs. /v/) based on this feature.[5]

The IPA category of **labialization** (secondary rounding on consonants, as in [k] vs. [kʷ]) can be treated by adding the features [+labial, +round] to whatever values the unlabialized version of the consonant has.

Here are some examples of segments that are [+labial] along with their feature values.

Plain bilabials	[p, b, m, ɸ, β]	[+labial, –round, –labiodental]
Plain labiodentals	[f, v]	[+labial, –round, +labiodental]
Rounded bilabials	[pʷ, bʷ, mʷ, ɸʷ, βʷ]	[+labial, +round, –labiodental]
Rounded labiodentals	[fʷ, vʷ]	[+labial, +round, +labiodental]

[4] [lateral] is, cross-linguistically, overwhelmingly a feature of coronals, and thus is listed in this section. A few languages have velar laterals.

[5] Distinctive feature theorists have often tried to handle the bilabial-labiodental contrast without adding a new feature. In one view, labiodentals are [–distributed], since they have short front-to-back closure. But this groups them together with the coronal apicals as a natural class, and to my knowledge there is no support for such a class from language data. Another approach is to say that labiodentals are [+strident], based on the fact that they are slightly louder than bilabial [ɸ] and [β]. This groups [f] and [v] with the sibilants, and once again there appears to be no support for such a grouping. For example, if [f] and [v] were [+strident], we would expect the plurals of *cuff* and *dove* to be *['kʌfəz] and *['dʌvəz]. I use [labiodental] instead of trying to shoehorn the labiodentals into a slot they don't fit.

Rounded velars	[w, k^{w}, g^{w}, x^{w}, g^{w}]	[+labial, +dorsal, +round, –labiodental]
Labial-velars	[k͡p, g͡b]	[+labial, +dorsal, –round, –labiodental]
Rounded coronals	[t^{w}, d^{w}, s^{w}, z^{w}, r^{w}]	[+labial, +coronal, +round, –labiodental]

4.6.4 Features used for classifying the dorsals

The [dorsal] articulator (tongue body) is special because it is also the primary articulator for vowels. One appealing strategy for describing the various consonants that can be made with the tongue body is to treat consonants as analogous to the closest similar vowel.

- Fronted velars (the kind in English *keen* [k̟in]) are treated as [+high, –low, +front, –back], like [i] and [y].
- Central velars (the kind in English *collect* [kəˈlɛkt]) are treated as [+high, –low, –front, –back], like [ɨ] and [ʉ].
- Back velars (the kind in English *coo* [k̠u][6] are treated as [+high, –low, –front, +back], like [ɯ] and [u].
- Uvulars (e.g. [q, ɢ, χ, ʁ]), are treated as [–high, –low, –front, +back], like [ɤ] and [o].
- Pharyngeals (e.g. [ħ, ʕ]), are treated as [–high, +low, –front, +back] like [ɑ] and [ɒ].

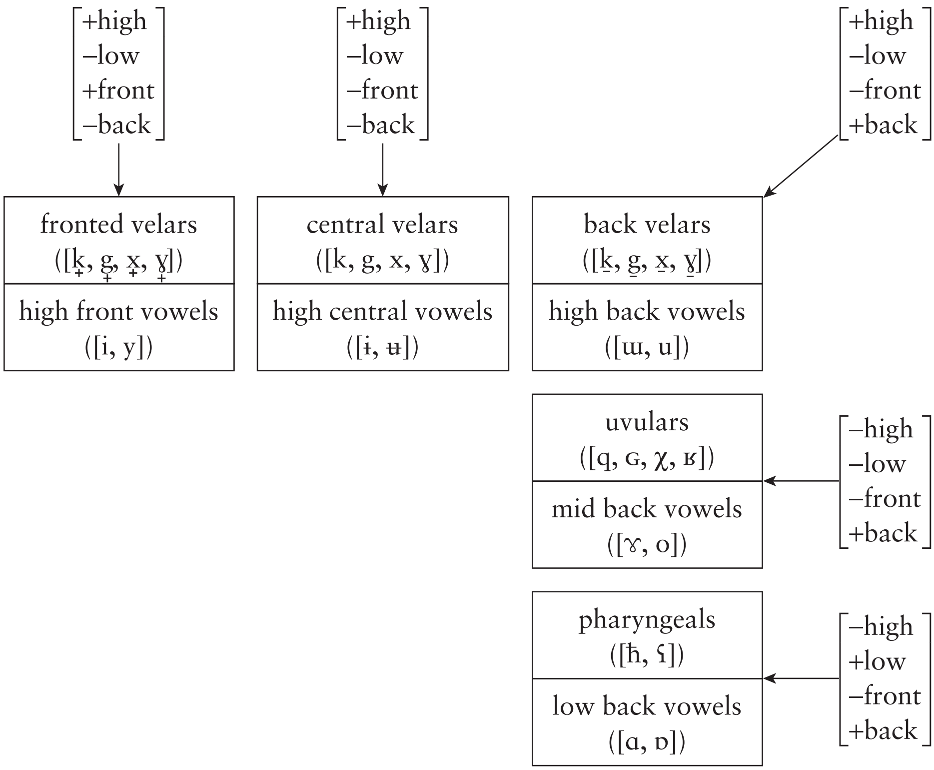
Table 4.5 shows the equivalences.

There is a certain sensibleness to this proposal, since these features are needed to describe tongue body position in vowels in any event. Moreover, there is a phonetic affinity between the consonants and vowels that are paired this way. English fronts its velars in the environment of front vowels and backs them in the neighborhood of back vowels, Eskimo languages lower their high vowels to mid when they precede uvulars, and Maltese Arabic lowers /i/ to [a] before pharyngeals. Under this feature system, all of these can be construed as assimilations (p. 57).

True palatals (IPA [c, ɟ, ç, ʝ, ɲ] are usually judged to involve the simultaneous participation of both tongue blade and tongue body. They are treated here as [+coronal, –anterior, +distributed, +dorsal, +high, –low, +front, –back].

[6] Caution: this example works only for dialects of English that have a true back vowel in *coo*. If you speak a dialect that has central /ʉ/ for this phoneme, then of course the allophone of /k/ that will appear before it will be central [k].

Table 4.5 Features used for classifying the dorsals



4.6.5 Secondary articulations

The tongue body also participates in secondary articulations, which can be described by adding the appropriate feature values to the base segment:

palatalization (IPA [ʲ]): add [+dorsal, +high, –low, +front, –back]
velarization (IPA [ˠ]): add [+dorsal, +high, –low, –front, +back]
pharyngealization (IPA [ˤ]): add [+dorsal, –high, +low, –front, +back]
labialization (IPA [ʷ]): add [+labial, +round]

4.6.6 "Place" as a group concept

It is commonly noted that the system of features should not be treated as some homogeneous collection, but instead is internally structured: one speaks of place features, manner features, laryngeal features, and a few other categories. Suppose that the following features are specified in the theory as the place features:

[labial]	[coronal]	[dorsal]
[round]	[anterior]	[high]
[labiodental]	[distributed]	[low]
	[strident]	[front]
	[lateral]	[back]

An interesting aspect of many phonological rules is that they manipulate all the place features at once. Thus, in Spanish and many other languages, when underlying /n/ is placed before another consonant, it assimilates in place to that consonant, no matter what place it bears.

in isolation:	[u**n**]	(masculine indefinite article)
before a vowel:	[u**n** oso]	‘a bear’
before bilabials:	[u**m** peso]	‘a peso’
	[u**m** beso]	‘a kiss’
before labiodentals:	[u**ɱ** foko]	‘a focus’
before dentals:	[u**n̪** t̪io]	‘an uncle’
	[u**n̪** d̪ia]	‘a day’
before alveolars:	[u**n** sako]	‘a sack’
before palatoalveolars:	[u**n̠** t͡ʃaɾko]	‘a pool’
before velars:	[u**ŋ** kakto]	‘a cactus’
	[u**ŋ** gato]	‘a cat’
	[u**ŋ** xweɣo]	‘a game’

Various proposals have been made for treating the place features as a unit. Here we will use the following notation:

/n/ Assimilation

$$n \rightarrow [\text{place}_i] \;/\; \_\_\_ \begin{bmatrix} -\text{syllabic} \\ \text{place}_i \end{bmatrix}$$

The notation “place_i” in the environment of the rule should be taken as meaning “all of the values for the place features.” Thus, the rule above assigns to /n/ all of the place feature values of the immediately following consonant. (For more on the notation of assimilation rules, see p. 133.)

4.7 Laryngeal Features

4.7.1 [voice]

[**voice**] can be defined articulatorily as involving vocal cord vibration, and acoustically as involving the characteristic periodic waveform that results from this vibration. [voice] defines a phonemic distinction among obstruents in the majority of languages, but is seldom phonemic among sonorant consonants, and virtually never phonemic among vowels. Voiceless vowels and sonorant consonants are quite common, however, as allophones.

4.7.2 [+spread glottis]

[+spread glottis] means that the vocal cords, riding on the arytenoid cartilages (see figure 1.2, p. 3) have been placed relatively far apart, producing a wide glottis. Phonologically, [+spread glottis] is present for [h], for breathy vowels, and for aspirated consonants. [+spread glottis] sounds are normally voiceless, but do occur voiced, notably in the voiced allophone of /h/ in English, [ɦ] (found between two vowels, as in *ahead* [əˈɦɛd]), in breathy vowels, and in the voiced aspirated stops [bʰ dʰ gʰ] found in many languages of India.

The phonetic affinity of [h] and aspirated stops appears to be phonologically relevant. For instance, Ancient Greek and other languages that forbid the appearance of two aspirated stops in the same root also tend to forbid the cooccurrence of aspirated stops and [h]. In English, the aspirated allophones of the voiceless stops occur in the same set of environments that /h/ does (see p. 54): word-initially (*perhaps* [**pʰ**ɚˈhæps], *Horatio* [**h**əˈɹeɪʃoʊ]), and medially before a stressed vowel (*competition* [ˌkʰɑmpəˈ**tʰ**ɪʃən], *prohibit* [proʊˈ**h**ɪbɪt]).

4.7.3 [+constricted glottis]

[+constricted glottis] is the opposite of [spread glottis], involving adduction of the vocal cords to make a narrow or closed glottis. The [+constricted glottis] sounds include the following:

- Glottal stop ([ʔ])
- Ejectives ([p’, t’, k’])
- Preglottalized sounds like the allophone of /t/ at the end of English *cat* [kæˀ**t**]
- The so-called “tense” stops of Korean, which have glottal closure but are not ejective. (conventional transcription: [p’, t’, k’])

The features [spread glottis] and [constricted glottis] divide a single phonetic continuum – glottal width – into three categories, [+spread glottis, −constricted glottis], [−spread glottis, −constricted glottis], and [−spread glottis, +constricted glottis]. The majority of speech sounds probably use “normal” phonation and thus are [−spread glottis, −constricted glottis].

4.7.4 [+implosive]

[+implosive] sounds involve a special articulatory gesture in which the larynx is lowered, creating a temporary partial vacuum.

4.8 Zero as a Feature Value

Consider a labial consonant like /p/. What is its value for dorsal features like [high], [low], [front], [back], or [tense]?

If the /p/ is a palatalized ([pʲ]) or velarized ([pˠ]) sound, then the answer is clear (§4.6.5): the palatalization or velarization requires us to invoke dorsal features ([+high, –low, +front, –back] for palatalization, [+high, –low, –front, +back] for velarization). However, where this is not the case, we have to look more closely at the phonetics.

It appears that in most languages with plain /p/, the position of the tongue body during the production of this sound is simply *whatever is most articulatorily convenient*, given the neighboring sounds. Thus, for instance, in [ipa], the tongue body does not adopt any particular position during the /p/; rather, it makes a smooth, continuous gesture moving from the high front position of /i/ to the low central position of /a/. In this sense, the /p/ could be said truly "not to care" about values for dorsal features.

In the system used here, this kind of situation is described by assigning the value **zero** to features for which a segment can be said "not to care." We can assume that in the phonetic realization of phonological form, such "don't care" segments normally are given a smooth contour for the relevant phonetic parameter, achieving a convenient transition among the sounds that do care. The notation used here is simply the digit 0, as in [0back, 0front, 0high, 0low] as the tongue body features for a "don't care" [p].

Velar consonants can often be argued, on the same grounds, to be [0back] and [0front]. In phonetic studies, the tongue body during a velar can sometimes be seen to be sliding along the palate, in smooth transition from the preceding to the following vowel. However, some velars have a specified frontness value; for instance the allophone of /k/ at the end of a word in Persian is [+front, –back], irrespective of the preceding vowel, as for example in [pɑk̟] 'pure'.

Zero values are also set up simply because the feature doesn't seem relevant to the sound in question; in this text sonorants are assumed to be [0delayed release] (this feature only classified obstruents), and low vowels are assumed to be [0tense].

For details on the particular features and segments assumed to have the zero value, see the feature charts at the end of this chapter.

4.9 When and How to Use Features in Writing Rules

4.9.1 *Features vs. phonetic symbols*

A fully explicit phonological analysis of a language would use no phonetic symbols. Only the feature matrices have theoretical status, and the phonetic symbols are meant only as convenient abbreviations for particular feature matrices.

On the other hand, one also wants to be able to describe phonologies in a way that is accessible to human inspection. My own feeling is that in semi-formal presentation, it is appropriate to use a mixed notation, using phonetic symbols where they lead to no harm, and features where they contribute insight. Here are ways in which rules benefit by writing them with features.

To capture a natural class. For example, as noted above (p. 75), Indonesian has a rule that deletes /ŋ/ before nasals, liquids, and glides, the set of sonorant consonants:

Indonesian /ŋ/ Deletion

$$\text{ŋ} \rightarrow \varnothing \;/\; \underline{\quad} \begin{bmatrix} -\text{syllabic} \\ +\text{sonorant} \end{bmatrix}$$

To capture an assimilation. We do this by showing that the assimilating segment adopts a feature value already possessed by one of its neighbors. For example, in English, /k, g, ŋ/ become fronted [k̟, g̟, ŋ̟] before front vowels, as in *keel* [ˈk̟il], *gale* [ˈg̟eɪl], or *dinghy* [ˈdɪŋ̟i]. This is an assimilation, which can be expressed by:

Velar Fronting

$$\begin{bmatrix} +\text{dorsal} \\ +\text{consonantal} \end{bmatrix} \rightarrow \begin{bmatrix} +\text{front} \\ -\text{back} \end{bmatrix} \;/\; \underline{\quad} \begin{bmatrix} +\text{syllabic} \\ +\text{front} \end{bmatrix}$$

To show that a change is minor; that is, of only one or two feature values. For example, if a rule changes (only) /p/ to [b], one would write p → [+voice] rather than p → b, to show that nothing other than [voice] is changing.

Otherwise use of plain symbols is a sensible way to make a rule easier to read, provided that it is understood that the "real" rule employs only feature matrices.

4.9.2 *Finding the features needed in a rule*

To find the particular features needed to define a natural class, it helps to start with the complete set of sounds in a language, then use just enough features to take away the sounds not wanted, leaving the target natural class in place. For

Table 4.6 Analysis with a separate devoicing rule for each fricative

Final /v/ Devoicing

$$\begin{bmatrix} -\text{sonorant} \\ +\text{continuant} \\ +\text{labial} \\ +\text{voice} \end{bmatrix} \rightarrow [-\text{voice}] \; / \; \_\_\_ \;]_{\text{Utterance}}$$

Final /z/ Devoicing

$$\begin{bmatrix} -\text{sonorant} \\ +\text{continuant} \\ +\text{anterior} \\ +\text{strident} \\ +\text{voice} \end{bmatrix} \rightarrow [-\text{voice}] \; / \; \_\_\_ \;]_{\text{Utterance}}$$

Final /ð/ Devoicing

$$\begin{bmatrix} -\text{sonorant} \\ +\text{continuant} \\ +\text{labial} \\ +\text{voice} \end{bmatrix} \rightarrow [-\text{voice}] \; / \; \_\_\_ \;]_{\text{Utterance}}$$

Final /ʒ/ Devoicing

$$\begin{bmatrix} -\text{sonorant} \\ +\text{continuant} \\ -\text{anterior} \\ +\text{strident} \\ +\text{voice} \end{bmatrix} \rightarrow [-\text{voice}] \; / \; \_\_\_ \;]_{\text{Utterance}}$$

instance, if you are seeking to describe the class of glides, you can use [–syllabic] to take away all of the vowels of the language, then [–consonantal] to get rid of the non-glide consonants. At this point, just the glides remain.

There are good reasons to include only just as many features in a rule as are needed. Here is an example. In English, all voiced fricatives can be realized as voiceless when they precede a pause; that is to say, they are at the end of an utterance.[7]

save	/seɪv/	[seɪf], [seɪv]
bathe	/beɪð/	[beɪθ], [beɪð]
maze	/meɪz/	[meɪs], [meɪz]
rouge	/ɹuʒ/	[ɹuʃ], [ɹuʒ]

Since there are four voiced fricatives in English, we could, in principle, write four rules, which in features could be expressed as in table 4.6.

But this flies in the face of our earlier principle that phonological rules make reference to natural classes; certainly a more elegant approach would be to adopt a single rule:

Final Fricative Devoicing

$$\begin{bmatrix} -\text{sonorant} \\ +\text{continuant} \\ +\text{voice} \end{bmatrix} \rightarrow [-\text{voice}] \; / \; \_\_\_ \;]_{\text{Utterance}} \quad \text{(optional)}$$

[7] You might imagine that this would create considerable confusion, but in fact a basic voiceless fricative can be distinguished in this context because it has shortened the preceding vowel: *safe* is [sĕɪf] while *save* is [seɪf] (or [seɪv]); and similarly with *mace* [mĕɪs] vs. *maze* [meɪs, meɪz]. For more on this, see §7.1.

In fact, there is more than just elegance at stake: unlike the four-rule approach, the single-rule approach makes predictions about new voiced fricatives that could, in principle, enter the language. For example, when I teach phonetics, I find that I am liable to devoice other final voiced fricatives if I am not careful; syllables like [aʐ] (retroflex) or [að̼] (linguo-labial) can come out by mistake as [aʂ] and [aθ̼]. I interpret this as a transfer effect (§3.2.3), with my native phonology applying to fricatives that are new to me, because they belong to the same natural class. The four-rule approach fails to predict this behavior.

Even where we can't test the generality of a rule in this way, it is widely felt that it is better science to adopt (tentatively) the more general hypothesis in the absence of evidence to the contrary, since it opens our eyes to the cases that ought to be tested.

4.9.3 Simplifying rules through vacuous application

Notice that Fricative Devoicing can be made even simpler, as follows:

Final Fricative Devoicing (shortened)

$$\begin{bmatrix}-\text{sonorant}\\+\text{continuant}\end{bmatrix} \rightarrow [-\text{voice}]\ /\ \underline{\quad}\ ]_{\text{Utterance}}$$

This rule would apply *also to voiceless fricatives* and "devoice" them – making no change at all, a form of vacuous application (p. 80). Although it is hard to imagine circumstances in which it would matter, phonologists usually do write their rules in this way, if only to keep them simpler and easier to read.

4.9.4 Features in the change of a rule

A common error in writing rules is to neglect some of the features needed in a change. For instance, rules of Tapping (t → ɾ), which occur in a variety of languages, cannot in general be stated as simply adding the feature [+tap], since various other features (such as [sonorant] and [voice]) must change at the same time. It helps to examine the complete list of feature values of both input and output segments, comparing them carefully.

4.10 Feature Charts

In tables 4.7–10 I have aimed at a compromise between maintaining reasonable size and broad coverage. Many sounds absent from the charts can have their

Table 4.7 Consonants I: single place of articulation

		Manner features								Laryngeal features			Place features													
		consonantal	sonorant	continuant	delayed release	approximant	tap	trill	nasal	voice	spread gl	constr gl	labial	round	labiodental	coronal	anterior	distributed	strident	lateral	dorsal	high	low	front	back	tense
bilabial	p	+	–	–	–	–	–	–	–	–	–	–	+	–	–	–	0	0	0	–	–	0	0	0	0	0
	b	+	–	–	–	–	–	–	–	+	–	–	+	–	–	–	0	0	0	–	–	0	0	0	0	0
	ɸ	+	–	+	+	–	–	–	–	–	–	–	+	–	–	–	0	0	0	–	–	0	0	0	0	0
	β	+	–	+	+	–	–	–	–	+	–	–	+	–	–	–	0	0	0	–	–	0	0	0	0	0
	m	+	+	–	0	–	–	–	+	+	–	–	+	–	–	–	0	0	0	–	–	0	0	0	0	0
	ʙ	+	+	+	0	+	–	+	–	+	–	–	+	–	–	–	0	0	0	–	–	0	0	0	0	0
labiodental	p͡f	+	–	–	+	–	–	–	–	–	–	–	+	–	+	–	0	0	0	–	–	0	0	0	0	0
	f	+	–	+	+	–	–	–	–	–	–	–	+	–	+	–	0	0	0	–	–	0	0	0	0	0
	v	+	–	+	+	–	–	–	–	+	–	–	+	–	+	–	0	0	0	–	–	0	0	0	0	0
	ɱ	+	+	–	0	–	–	–	+	+	–	–	+	–	+	–	0	0	0	–	–	0	0	0	0	0
	ʋ	–	+	+	0	+	–	–	–	+	–	–	+	–	+	–	0	0	0	–	–	0	0	0	0	0
dental	t̪	+	–	–	–	–	–	–	–	–	–	–	–	–	–	+	+	+	–	–	–	0	0	0	0	0
	d̪	+	–	–	–	–	–	–	–	+	–	–	–	–	–	+	+	+	–	–	–	0	0	0	0	0
	θ	+	–	+	+	–	–	–	–	–	–	–	–	–	–	+	+	+	–	–	–	0	0	0	0	0
	ð	+	–	+	+	–	–	–	–	+	–	–	–	–	–	+	+	+	–	–	–	0	0	0	0	0
alveolar	t	+	–	–	–	–	–	–	–	–	–	–	–	–	–	+	+	–	–	–	–	0	0	0	0	0
	d	+	–	–	–	–	–	–	–	+	–	–	–	–	–	+	+	–	–	–	–	0	0	0	0	0
	t͡s	+	–	–	+	–	–	–	–	–	–	–	–	–	–	+	+	–	+	–	–	0	0	0	0	0
	d͡z	+	–	–	+	–	–	–	–	+	–	–	–	–	–	+	+	–	+	–	–	0	0	0	0	0
	t͡ɬ	+	–	–	+	–	–	–	–	–	–	–	–	–	–	+	+	–	–	+	–	0	0	0	0	0
	s	+	–	+	+	–	–	–	–	–	–	–	–	–	–	+	+	–	+	–	–	0	0	0	0	0
	z	+	–	+	+	–	–	–	–	+	–	–	–	–	–	+	+	–	+	–	–	0	0	0	0	0
	n	+	+	–	0	–	–	–	+	+	–	–	–	–	–	+	+	–	–	–	–	0	0	0	0	0
	l	+	+	+	0	+	–	–	–	+	–	–	–	–	–	+	+	–	–	+	–	0	0	0	0	0
	ɬ	+	–	+	+	–	–	–	–	–	–	–	–	–	–	+	+	–	–	+	–	0	0	0	0	0
	ɮ	+	–	+	+	–	–	–	–	+	–	–	–	–	–	+	+	–	–	+	–	0	0	0	0	0
	ɾ	+	+	+	0	+	+	–	–	+	–	–	–	–	–	+	+	–	–	–	–	0	0	0	0	0
	ɺ	+	+	+	0	+	+	–	–	+	–	–	–	–	–	+	+	–	–	+	–	0	0	0	0	0
	r	+	+	+	0	+	–	+	–	+	–	–	–	–	–	+	+	–	–	–	–	0	0	0	0	0
palato-alveolar	t͡ʃ	+	–	–	+	–	–	–	–	–	–	–	–	–	–	+	–	+	+	–	–	0	0	0	0	0
	d͡ʒ	+	–	–	+	–	–	–	–	+	–	–	–	–	–	+	–	+	+	–	–	0	0	0	0	0
	ʃ	+	–	+	+	–	–	–	–	–	–	–	–	–	–	+	–	+	+	–	–	0	0	0	0	0
	ʒ	+	–	+	+	–	–	–	–	+	–	–	–	–	–	+	–	+	+	–	–	0	0	0	0	0
	ɹ	–	+	+	0	+	–	–	–	+	–	–	–	–	–	+	–	+	–	–	–	0	0	0	0	0

Table 4.7 (*cont'd*)

		Manner features								Laryngeal features			Place features													
		consonantal	sonorant	continuant	delayed release	approximant	tap	trill	nasal	voice	spread gl	constr gl	labial	round	labiodental	coronal	anterior	distributed	strident	lateral	dorsal	high	low	front	back	tense
retroflex	ʈ	+	−	−	−	−	−	−	−	−	−	−	−	−	−	+	−	−	−	−	−	0	0	0	0	0
	ɖ	+	−	−	−	−	−	−	−	+	−	−	−	−	−	+	−	−	−	−	−	0	0	0	0	0
	ʂ	+	−	+	+	−	−	−	−	−	−	−	−	−	−	+	−	−	+	−	−	0	0	0	0	0
	ʐ	+	−	+	+	−	−	−	−	+	−	−	−	−	−	+	−	−	+	−	−	0	0	0	0	0
	ɳ	+	+	−	0	−	−	−	+	+	−	−	−	−	−	+	−	−	−	−	−	0	0	0	0	0
	ɭ	+	+	+	0	+	−	−	−	+	−	−	−	−	−	+	−	−	−	+	−	0	0	0	0	0
	ɽ	+	+	+	0	+	+	−	−	+	−	−	−	−	−	+	−	−	−	−	−	0	0	0	0	0
	ɻ	+	+	+	0	+	−	−	−	+	−	−	−	−	−	+	−	−	−	−	−	0	0	0	0	0
fronted velar	k̟	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−	0	0	0	−	+	+	−	+	−	0
	g̟	+	−	−	−	−	−	−	−	+	−	−	−	−	−	−	0	0	0	−	+	+	−	+	−	0
	x̟	+	−	+	+	−	−	−	−	−	−	−	−	−	−	−	0	0	0	−	+	+	−	+	−	0
	j	−	+	+	0	+	−	−	−	+	−	−	−	−	−	−	0	0	0	−	+	+	−	+	−	+
velar	k	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−	0	0	0	−	+	+	−	0	0	0
	g	+	−	−	−	−	−	−	−	+	−	−	−	−	−	−	0	0	0	−	+	+	−	0	0	0
	ŋ	+	+	−	0	−	−	−	+	+	−	−	−	−	−	−	0	0	0	−	+	+	−	0	0	0
	k͡x	+	−	−	+	−	−	−	−	−	−	−	−	−	−	−	0	0	0	−	+	+	−	0	0	0
	x	+	−	+	+	−	−	−	−	−	−	−	−	−	−	−	0	0	0	−	+	+	−	0	0	0
	ɣ	+	−	+	+	−	−	−	−	+	−	−	−	−	−	−	0	0	0	+	+	+	−	0	0	0
	ʟ	+	+	+	0	+	−	−	−	+	−	−	−	−	−	−	0	0	0	−	+	+	−	0	0	0
back velar	k̠	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−	0	0	0	+	+	+	−	−	+	0
	g̠	+	−	−	−	−	−	−	−	+	−	−	−	−	−	−	0	0	0	−	+	+	−	−	+	0
	x̠	+	−	+	+	−	−	−	−	−	−	−	−	−	−	−	0	0	0	−	+	+	−	−	+	0
	ɣ̠	+	−	+	+	−	−	−	−	+	−	−	−	−	−	−	0	0	0	−	+	+	−	−	+	0
uvular	q	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−	0	0	0	−	+	−	−	−	+	0
	ɢ	+	−	−	−	−	−	−	−	+	−	−	−	−	−	−	0	0	0	−	+	−	−	−	+	0
	χ	+	−	+	+	−	−	−	−	−	−	−	−	−	−	−	0	0	0	−	+	−	−	−	+	0
	ʁ	+	−	+	+	−	−	−	−	+	−	−	−	−	−	−	0	0	0	−	+	−	−	−	+	0
	ɴ	+	+	−	0	−	−	−	+	+	−	−	−	−	−	−	0	0	0	−	+	−	−	−	+	0
	ʀ	+	+	+	0	+	−	+	−	+	−	−	−	−	−	−	0	0	0	−	+	−	−	−	+	0
pharyn	ħ	+	−	+	+	−	−	−	−	−	−	−	−	−	−	−	0	0	0	−	+	−	+	−	+	0
	ʕ	+	−	+	−	−	−	−	−	+	−	−	−	−	−	−	0	0	0	−	+	−	+	−	+	0
glottal	ʔ	+	−	−	−	−	−	−	−	−	−	+	−	−	−	−	0	0	0	−	−	0	0	0	0	0
	h	−	−	+	+	−	−	−	−	−	+	−	−	−	−	−	0	0	0	−	−	0	0	0	0	0
	ɦ	−	−	+	+	−	−	−	−	+	+	−	−	−	−	−	0	0	0	−	−	0	0	0	0	0

Table 4.8 Consonants II: complex segments

		Manner features								Laryngeal features			Place features													
		consonantal	sonorant	continuant	delayed release	approximant	tap	trill	nasal	voice	spread gl	constr gl	labial	round	labiodental	coronal	anterior	distributed	strident	lateral	dorsal	high	low	front	back	tense
labial-back velar	w	–	+	+	0	+	–	–	–	+	–	–	+	+	–	–	0	0	0	–	+	+	–	–	+	+
	ʍ	–	–	+	+	–	–	–	–	–	+	–	+	+	–	–	0	0	0	–	+	+	–	–	+	+
labial-velar	k͡p	+	–	–	–	–	–	–	–	–	–	–	+	–	–	–	0	0	0	–	+	+	–	0	0	0
	g͡b	+	–	–	–	–	–	–	–	+	–	–	+	–	–	–	0	0	0	–	+	+	–	0	0	0
labial-front velar	ɥ	–	+	+	0	+	–	–	–	+	–	–	+	+	–	–	0	0	0	–	+	+	–	+	–	+
alveolopalatal	t͡ɕ	+	–	–	+	–	–	–	–	–	–	–	–	–	–	+	+	+	+	–	+	+	–	+	–	0
	d͡ʑ	+	–	–	+	–	–	–	–	+	–	–	–	–	–	+	+	+	+	–	+	+	–	+	–	0
	ɕ	+	–	+	+	–	–	–	–	–	–	–	–	–	–	+	+	+	+	–	+	+	–	+	–	0
	ʑ	+	–	+	+	–	–	–	–	+	–	–	–	–	–	+	+	+	+	–	+	+	–	+	–	0
palatal	c	+	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	+	–	–	+	+	–	+	–	0
	ɟ	+	–	–	–	–	–	–	–	+	–	–	–	–	–	+	–	+	–	–	+	+	–	+	–	0
	ç	+	–	+	+	–	–	–	–	–	–	–	–	–	–	+	–	+	–	–	+	+	–	+	–	0
	ʝ	+	–	+	+	–	–	–	–	+	–	–	–	–	–	+	–	+	–	–	+	+	–	+	–	0
	ɲ	+	+	–	0	–	–	–	+	+	–	–	–	–	–	+	–	+	–	–	+	+	–	+	–	0
	ʎ	+	+	+	0	+	–	–	–	+	–	–	–	–	–	+	–	+	–	+	+	+	–	+	–	0

features deduced by looking up a similar sound and changing the most obvious features; or you can try using the FeaturePad software listed in the Preface to this book. A more complete feature chart can be downloaded as a spreadsheet from www.linguistics.ucla.edu/people/hayes/120a/index.htm#features.

4.10.1 Consonants I: single place of articulation

For consonants that have two places of articulation (complex segments), see the next section. All consonants are [–syllabic], and this feature is not included in the chart.

4.10.2 Consonants II: complex segments

These segments have two places of articulation. They are all [–syllabic], so this feature is not included in the chart.

4.10.3 Vowels

The basic features for vowels (shown in table 4.9 by the basic IPA symbols rather than the diacritics) are [round], [high], [low], [front], and [back]. [labial] is predictable, occurring only in [+round] vowels. All other features are invariant; unless overridden by a diacritic, all vowels are [+syllabic, –consonantal, +sonorant, +continuant, 0delayed release, +approximant, –tap, –trill, –nasal, +voice, –spread glottis, –constricted glottis, –labiodental, –coronal, 0anterior, 0distributed, 0strident].

Table 4.9 Vowels

	high tense						high lax			mid tense					
	i	y	ɨ	ʉ	ɯ	u	ɪ	ʏ	ʊ	e	ø	ɘ	ɵ	ɤ	o
[high]	+	+	+	+	+	+	+	+	+	–	–	–	–	–	–
[low]	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
[tense]	+	+	+	+	+	+	–	–	–	+	+	+	+	+	+
[front]	+	+	–	–	–	–	+	+	–	+	+	–	–	–	–
[back]	–	–	–	–	+	+	–	–	+	–	–	–	–	+	+
[round]	–	+	–	+	–	+	–	+	+	–	+	–	+	–	+

	mid lax						low				
	ɛ	œ	ə	ɞ	ʌ	ɔ	æ	ɶ	a	ɑ	ɒ
[high]	–	–	–	–	–	–	–	–	–	–	–
[low]	–	–	–	–	–	–	+	+	+	+	+
[tense]	–	–	–	–	–	–	0	0	0	0	0
[front]	+	+	–	–	–	–	+	+	–	–	–
[back]	–	–	–	–	+	+	–	–	–	+	+
[round]	–	+	–	+	–	+	–	+	–	–	+

4.10.4 *Diacritics*

Table 4.10 Diacritics

Diacritic	**As applied to**	**Phonetic definition**	**Designates these features**
̩	a consonant	syllabic	[+syllabic]
̰	voiced sounds	creaky voice	[–spread glottis, +constricted glottis]
̤	voiced sounds	breathy voice	[+spread glottis, –constricted glottis]
̥	voiced sounds	voiceless	[–voice]
̠	alveolar	palato-alveolar	[–anterior, +distributed]
̪	alveolar	dental	[+anterior, +distributed]
̟	velar	fronted velar	[+front, –back]
̠	velar	backed velar	[–front, +back]
ˈ	before a syllable	stressed	[+stress]
ː	any segment	long	[+long]
ʰ	a consonant	aspirated	[+spread glottis, –constricted glottis]
ʲ	a consonant	palatalized	[+dorsal, +high, –low, +front, –back]
ʷ	a consonant	labialized	[+labial, +round]
ˠ	a consonant	velarized	[+dorsal, +high, –low, –front, +back]
ˠ	a consonant	pharyngealized	[+dorsal, –high, +low, –front, +back]
̃	a sonorant	nasalized	[+nasal]
˞	a vowel	rhotic	[+coronal, +anterior, +distributed, –strident]
ʼ	an obstruent	ejective	[–spread glottis, +constr glottis]

Exercises

Note: for software that may help in doing feature exercises, see discussion of "FeaturePad" in the Preface to this book.

1 *Natural classes*

Assume the vowel inventory shown in table 4.11 and the features [high], [low], [back], and [round] as defined in §4.10.3. For the sake of simplicity, ignore [front] and [tense].

Table 4.11 Vowel chart for exercise 1

Vowels:	Front		Back	
	Unrounded	Rounded	Unrounded	Rounded
high	i	y	ɯ	u
mid	e	ø	ɤ	o
low	æ	ɶ	ɑ	ɒ

a. Find as many natural classes as you can that have four members. List them, and define the natural class using features.
b. Find as many natural classes as you can that have six members. List them, and define the natural class using features.
c. Find as many natural classes as you can that have eight members. List them, and define the natural class using features.
d. Find as many natural classes as you can that have five members.
e. Explain why [y, e] is not a natural class.

2 *Hypothetical language*

A hypothetical language has the phonemes shown in table 4.12.

Table 4.12 Consonant chart for exercise 2

Consonants	Labial	Alveolar	Palatoalveolar	Fronted Velar	Velar	Uvular	Pharyngeal	Glottal
Stops	p	t		k̟	k	q		ʔ
Affricates		t͡s						
Fricatives	f	s	ʃ	x̟	x	χ	ħ	h
Nasals	m	n	n̠	ŋ̟	ŋ	ɴ		
Liquids: Tap Lateral		ɾ l						
Glides	w			j				

Vowels: as in previous problem.

Write the following phonological rules of this language using the features presented in this chapter. In each case I have indicated the real-life rule on which I have modeled the imaginary rule. Some problems will arise in notation; read the footnotes for help with these.

1 [i, y, ɯ, u] become [e, ø, ɤ, o] before [q, ɴ]. (modeled on Eskimo languages)
2 [t] becomes [t͡s] before [i, y, ɯ, u]. (modeled on Japanese)
3 [i, e, æ] become [j] before a vowel. (modeled on Ilokano)
4 When a member of the group [s, t͡s, ʃ] is followed by a member of the group [s, ʃ], the resulting cluster is broken up by the insertion of [i]. Use features, not a phonetic symbol, for [i]. (modeled on English)
5 [n] assimilates in place to a following stop or affricate. (modeled on Ilokano)
6 All consonants except /t, t͡s, s, n, ɾ, l, ʃ, n̠/ delete word-finally. (modeled on Lardil (Australia))
7 [l] becomes [ɾ] if another [l] precedes it anywhere in the word.[8] (modeled on Latin)
8 [ʔ] changes places with an immediately following glide.[9] (modeled on Ilokano)
9 All unrounded vowels become [ɑ], and all rounded vowels become [ɒ], before [ħ]. (modeled on Maltese Arabic)
10 [e] and [ɤ] become [ø] and [o] if a [ø] or [o] occurs in the preceding syllable.[10] (modeled on Khalkha Mongolian)
11 [k, x, ŋ] become [k̟, x̟, ŋ̟] after [i, j]. (modeled on German)

Further reading

Representations in other areas of cognitive science: Fred Lerdahl and Ray Jackendoff, *A Generative Theory of Tonal Music* (1983, MIT Press); David Marr, *Vision*: A *Computational Investigation into the Human Representation and Processing of Visual Information* (1982, W. H. Freeman).

[8] The notation to use here is a "variable," like X. X means "any number of segments of any type." So, for instance, the Sibilant Harmony rule from child speech mentioned above (p. 85) was something like:

s → ʃ / ___ X ʃ

[9] Here is how to do the concept "changes places with." Put a number underneath each segment in the rule. Then, on the right side of the arrow, list everything in the input, using the numbers to show what has changed places. So, for instance, this rule:

V	t	p	V	→	V	p	t	V
1	2	3	4		1	3	2	4

means "reverse the order of /tp/ when surrounded by vowels."

[10] You need a way to describe the notion "vowel of the preceding/next syllable." For the notation that is needed, look at the rule on p. 154.

Most of the features here are taken from Chomsky and Halle's *The Sound Pattern of English* (1968, Harper and Row). An earlier important work that developed the idea of acoustic features is Roman Jakobson, Gunnar Fant, and Morris Halle, *Preliminaries to Speech Analysis* (1963, MIT Press).

Eduard Sievers on sonority: *Grundzüge der Phonetik*, chapter 3, §2 (5th ed., 1901, Breitkopf und Härtel). The feature [approximant]: G. N. Clements, "The role of the sonority cycle in core syllabification," in John Kingston and Mary E. Beckman, eds., *Papers in Laboratory Phonology I: Between the Grammar and Physics of Speech* (1990, Cambridge University Press). See the same reference (including references cited therein) for the idea of analyzing the sonority hierarchy with a set of features, each defining a cutoff point. Palatals as [+coronal, +dorsal]: Patricia Keating (1988) "Palatals as complex segments: X-ray evidence," *UCLA Working Papers in Phonetics* 69: 77–91.

Phonetic evidence for zero feature values (with smooth transition between the values for neighboring segments): Patricia A. Keating (1988) "Underspecification in phonetics," *Phonology* 5: 275–92.

Syllabic stops and fricatives in Berber: François Dell and Mohamed Elmedlaoui, *Syllables in Tashlhiyt Berber and in Moroccan Arabic* (2002, Springer). Tonal restrictions as an argument for the feature [sonorant]: Matthew Gordon (2001) "A typology of contour tone restrictions," *Studies in Language* 25: 405–44. Kongo affrication: George N. Clements and Morris Halle, *A Problem Book in Phonology* (1983, MIT Press). Arabic assimilation of /l/ to coronals: Alan S. Kaye, "Arabic," in Bernard Comrie, ed., *The World's Major Languages* (1987, Oxford University Press). Vowel lowering and voicing assimilation in Maltese Arabic: Michael K. Brame, "On the abstractness of phonology: Maltese ʕ," in Michael K. Brame, ed., *Contributions to Generative Phonology*, pp. 22–61 (1972, University of Texas Press). Indonesian ŋ deletion: Hans Lapoliwa, *A Generative Approach to the Phonology of Bahasa Indonesia* (1981, Australian National University). Spanish nasal assimilation: James Harris, *Spanish Phonology* (1969, MIT Press).