2 Phonemic Analysis

2.1 Phonology and Phonetics

As noted in the previous chapter, there are two branches of linguistics that deal with speech sounds. Phonetics studies speech sounds in ways that are close to the speech stream, focusing on production, acoustics, and perception. Phonology tends to be more abstract, dealing not directly with the physical nature of speech sounds (though that is of course quite relevant), but rather with the largely unconscious **rules** for sound patterning that are found in the mind/brain of a person who speaks a particular language. It could be said that a phonologist is a kind of grammarian, and the area of grammar that she studies is the sound pattern of a language.

The rules studied by phonologists come in various kinds. First, phonetic study shows that sounds *vary with their context*, often in complex ways; and phonologists hypothesize rules to characterize this variation. Second, the *sequencing and distribution* of speech sounds is not arbitrary, but follows patterns also describable with rules. Third, phonology is *interfaced* with other components of the grammar, particularly morphology and syntax, and there are rules that characterize the way in which sound patterning reflects information that arises within these components.

The phonologies of many languages often show a level of complexity that make them a worthwhile intellectual challenge for the phonologist trying to understand them. It can take many years of careful research to fully explicate the sound pattern of a language. What is remarkable is that the same pattern is learned quite rapidly, at the intuitive level, by humans when they are exposed to it in childhood.

2.2 Distinctiveness and Contrast

The sounds of a language are intrinsically meaningless: their only purpose is to form the building blocks of which words are made. For example, because English has the sounds [t] and [d], the possibility exists of English having the word *time* [taɪm], distinct from the word *dime* [daɪm]. One could put it this way: the only real purpose of a speech sound is to sound different from the other sounds of the language; this is what makes a spoken vocabulary possible.

To begin the analysis of a language's phonology, we therefore seek to locate all of its basic sounds, the minimal units that serve to distinguish words from each other. These basic speech sounds are the **phonemes** of the language. The phonemes of one commonly spoken dialect of American English are arranged phonetically in tables 2.1 and 2.2; that is, more or less in the manner of the IPA chart, though not necessarily the exact same rows, columns, or order that the IPA uses. The sound symbols are in slant brackets, which is the standard way of indicating phonemes. An example word is given beneath each phoneme to illustrate it.

Other English dialects differ from the above, having additional phonemes such as /ʍ/, /ʌɪ/, /ɛə/, /ɒ/; or fewer phonemes.

Languages vary in their number of phonemes. The record low is believed to be held by Rotokas (East Papuan, New Guinea), with 11, and the record high by !Xóõ (Khoisan, Botswana/Namibia), with 160. English has roughly 37–41, depending on the dialect and the analysis. The average across languages is about 30.

Below, we will discuss detailed methods for establishing the phoneme inventory of a language or dialect. But the most important point can be stated right away: *if any two words of a language are pronounced differently, they must differ in at least one phoneme*. This follows from the basic idea of the phoneme; that is, that the phoneme inventory is the set of "building blocks" out of which all the words of the language are constructed.

The example given above, *time* [taɪm] vs. *dime* [daɪm], was strategically arranged to make this point. These words are identical, except for their initial sounds; that is, they are both of the form [Xaɪm]. Since they are different words, it follows that [t] and [d] are distinct sounds; that is, they are separate phonemes. A pair like ([taɪm], [daɪm]), differing in just one single location, is called a **minimal pair**. A minimal pair is the most effective way to show that two sounds are distinct phonemes.

There are quite a few ways in phonology of saying that two sounds are separate phonemes. Equivalently, we say that the English sounds /t/ and /d/ **contrast** with each other, that they are **in contrast**, or that they are **phonemically distinct**, or that the difference between them is **distinctive**. All of these terms are essentially equivalent.

The concept of minimal pair can be extended to cover larger sets. A set like *time* [taɪm] – *dime* [daɪm] – *lime* [laɪm] is a **minimal triplet**, showing that /t/, /d/, and /l/ are distinct phonemes; and the concept clearly generalizes to as many members as one can find. Tables 2.1 and 2.2 include examples forming a minimal 13-tuplet for consonants and a minimal 12-tuplet for vowels. Such sets are useful for demonstrating a large fraction of the phonemic system of a language all at once.

Table 2.1 English phonemes: consonants

		Bilabial	*Labiodental*	*Dental*	*Alveolar*	*Palatoalveolar*	*Palatal*	*Velar*	*Glottal*
Stops	*voiceless*	/p/ pin			/t/ tin			/k/ kin	
	voiced	/b/ bin			/d/ din			/g/ gill	
Affricates	*voiceless*					/tʃ/ chin			
	voiced					/dʒ/ gin			
Fricatives	*voiceless*		/f/ fin	/θ/ thin	/s/ sin	/ʃ/ shin			/h/ hymn
	voiced		/v/ vim	/ð/ this	/z/ zip	/ʒ/ vision			
Nasals		/m/ mitt			/n/ nip			/ŋ/ sing	
Approximants	*lateral*				/l/ Lynn				
	central	/w/ win			/ɹ/ rim		/j/ ying		

Table 2.2 English phonemes: vowels and diphthongs

	Front Unrounded	*Central Unrounded*	*Back*		*Diphthongs*
			Unrounded	*Rounded*	
Upper high	/i/ beat			/u/ boot	/aɪ/, /aʊ/, /ɔɪ/ bite, bout, Coit
Lower high	/ɪ/ bit			/ʊ/ foot	
Upper mid	/eɪ/ bait	/ə/ abbot		/oʊ/ boat	*Rhotacized upper mid central unrounded*
Lower mid	/ɛ/ bet		/ʌ/ but	/ɔ/ bought	
Low	/æ/ bat		/ɑ/ father		/ɚ/ Bert

2.3 Sounds that Do Not Contrast

For a reason to be given, there are also many pairs of sounds (in any language) that do *not* contrast. Here is a simple case from English, involving the length of vowels. If you listen to a native speaker say the following pairs of words (or better, measure with acoustic equipment), you will find that the vowel phoneme /eɪ/ is quite a bit **shorter** in the second member of each pair. I've indicated this in the transcription with the IPA shortness marker on the [e] part of the [eɪ] diphthong:

save	[seɪv]	*safe*	[sĕɪf]
Abe	[eɪb]	*ape*	[ĕɪp]
made	[meɪd]	*mate*	[mĕɪt]
maze	[meɪz]	*mace*	[mĕɪs]
age	[eɪdʒ]	*H*	[ĕɪtʃ]
Haig	[heɪg]	*ache*	[ĕɪk]

Although [eɪ] and [ĕɪ] are audibly different, they are not separate phonemes – one could not use them to form a distinction between words. The reason is that their distribution is predictable. In the data given, which are representative, there is a straightforward fact that determines which of the two will appear. (You should take a look at the data now if you have not yet seen what this factor is.)

The relevant factor is the voicing of the immediately following sound. [eɪ] occurs when this sound in the word is voiced (here: [v, b, d, z, dʒ, g]), and [ĕɪ] occurs when the next sound in the word in voiceless (here: [f, p, t, s, tʃ, k]). The fact that the appearance of [eɪ] vs. [ĕɪ] is predictable is important, because it shows that the difference between the two could never be the (sole) distinction between words; there will always be a difference in the voicing of the following consonant as well. It follows that there can be no minimal pair for [eɪ] and [ĕɪ].

A term that is commonly used to describe this is **complementary distribution**: two sounds are said to be in complementary distribution if one sound never occurs in the environments in which the other occurs.

Thus, in phonological analysis, for any pair of sounds it is necessary to establish their phonological status: either they are separate phonemes, capable of distinguishing words, or mere variants, whose distribution in the language is determined by context, in a way that can be expressed by a rule (here, the rule relating length to voicing). We will see refinements on this point later on, but it will suffice for now.

To complete the description of [eɪ] and [ĕɪ], we must dispose of an alternative possibility: that [eɪ] and [ĕɪ] really are distinct phonemes, and it is the voicing of the following consonant that is predictable. This possibility is eliminated by the fact that minimal pairs occur for consonant voicing in other contexts (for example, *few* vs. *view*); thus it has to be the voicing that is phonemic and the length that is predictable.

2.4 Phonemes as Categories

Another important aspect of the [eɪ]–[ĕɪ] data under discussion is that virtually every English speaker is unaware of the difference until it has been pointed out. That is to say, speakers are willing, intuitively, to accept [eɪ] and [ĕɪ] as being the "same vowel."[1] Phonologists hypothesize that sounds [eɪ] and [ĕɪ] in the present case (and similarly in parallel cases) form an abstract phonological *category*, namely, the phoneme /eɪ/. The concrete, observable sounds [eɪ] and [ĕɪ] are called the **allophones** of /eɪ/. This is illustrated as follows:

Abstract level:	/eɪ/		phoneme
Concrete level:	[eɪ]	[ĕɪ]	allophones
	used before voiced consonants	used before voiceless consonants	environments for allophones

[1] This is true even when the sounds are spelled differently, as in *Haig* vs. *ache*. The intuitive judgments are of sound, not spelling.

The idea is that the fundamental phonological categories (the phonemes) can be used to distinguish words from each other, but the variants of a particular phoneme (the allophones), cannot. As a metaphor, you could imagine that the phoneme inventory of a language is the fundamental "alphabet" (an alphabet of sound) out of which all the words of a language are composed; but each letter is subject to contextual variation. At the level of conscious awareness, people are characteristically attuned only to the distinctions between phonemes; to make people aware of allophones requires that their attention be carefully directed to the distinction.

2.5 More Instances of Allophonic Variation

Before moving on, let us consider some other cases of allophonic variation in English. The following pair illustrates words containing alveolar [n] and dental [n̪]. Check the environments for each sound, establishing the complementary distribution, before you read further.

Words with [n]		**Words with [n̪]**	
know	[ˈnoʊ]	*tenth*	[ˈtɛn̪θ]
annoy	[əˈnɔɪ]	*month*	[ˈmʌn̪θ]
onion	[ˈʌnjən]	*panther*	[ˈpæn̪θɚ]
nun	[ˈnʌn]	*chrysanthemum*	[kɹəˈsæn̪θəməm]

It is not hard to see that the dental [n̪] occurs in a specific context: before [θ]. There is no particular context for alveolar [n]; it occurs pretty much everywhere else. Thus, the phonemic pattern is as follows:

Abstract level:	/n/		phoneme
Concrete level:	[n̪]	[n]	allophones
	used before [θ]	used elsewhere	environments for allophones

The "elsewhere" environment seen here is quite common in phonology, and cases like the [n] in this example are often called **elsewhere allophones**. The allophone [eɪ], seen in the previous example, is actually an elsewhere allophone; it occurs not just before voiced consonants, but at the end of a word, as in *bay* [beɪ] or *day* [deɪ].

The next data set illustrates four allophones of the /l/ phoneme as they occur in a number of dialects of English. [ɫ] is a velarized l, articulated with high back tongue body position. [ɫ̪] is the same as [ɫ], only with a dental instead of alveolar place of articulation. [l̥͡l] is an l which starts out voiceless and ends voiced. Before you read further, inspect the following data and determine the environment characterizing each sound.

Words with [ɫ]		**Words with [l̥͡l]**		**Words with [ɫ̪]**		**Words with [l]**	
file	[ˈfaɪɫ]	*slight*	[ˈsl̥͡laɪt]	*wealth*	[ˈwɛɫ̪θ]	*listen*	[ˈlɪsən]
fool	[ˈfuɫ]	*flight*	[ˈfl̥͡laɪt]	*health*	[ˈhɛɫ̪θ]	*lose*	[ˈluz]
all	[ˈɔɫ]	*plow*	[ˈpl̥͡laʊ]	*filthy*	[ˈfɪɫ̪θi]	*allow*	[əˈlaʊ]
ball	[ˈbɔɫ]	*cling*	[ˈkl̥͡lɪŋ]	*tilth*	[ˈtɪɫ̪θ]	*aglow*	[əˈgloʊ]
fell	[ˈfɛɫ]	*discipline*	[ˈdɪsəpl̥͡lən]	*stealth*	[ˈstɛɫ̪θ]	*blend*	[ˈblɛnd]
feel	[ˈfiɫ]						

The pattern can be described as follows:

/l/

/ɫ/	/l̥͡l/	/ɫ̪/	/l/
at the ends of words	when the preceding consonant is voiceless	before [θ]	elsewhere

As before, this description appears to hold for the entire language, not just the sample data given here. Since none of these environments overlap,[2] the description establishes complementary distribution, and we can claim that all four of these sounds are allophones of the same phoneme.

The three examples just given are only the tip of the iceberg; in fact, virtually all the phonemes in English show variation based on their context. If we looked at English in full phonetic detail, taking all the allophonic variation into account, we would find that it has not several dozen speech sounds, but thousands.

All this gives rise to an overview of how a phonological system is "designed." In every language, the number of sounds that can be uttered is very large. But the phonological system organizes these sounds in a particular way, such that only a small subset of phonetic differences (for example, in English [t] vs. [d], or [ɪ] vs. [ɛ]) can serve to distinguish words. The remaining phonetic differences are allophonic, and determined by rule.

2.6 Phonemic Transcription

When a linguist records words as sequences of phonemes (under a particular phonemic analysis), the result is termed a **phonemic transcription**. This is to be

[2] The environments "after a voiceless consonant" and "at the end of a word" cannot overlap, because English has no words ending in a voiceless consonant followed by /l/.

distinguished from a **phonetic transcription**, which includes allophonic detail – the degree of detail recorded being up to the transcriber. The term **orthographic transcription** simply means that the words are written down using the customary spelling system (orthography) of the language. Below I give the same sentence in orthographic, phonemic, and phonetic transcription.

This is an orthographic transcription.	
/ðɪs ɪz ə foʊˈnimɪk trænˈskɹɪpʃən/	(This is a phonemic transcription.)
[ˈd̪͡ðɪs ɨz ə fə̃ˈnɛɾɨˀk t͡ʂʰɹɛ͡ə̃nˈskɹɪpʃɨ̃n]	(This is a phonetic transcription.)

The attractiveness of a phonemic transcription for practical purposes is that it is far simpler than a phonetic transcription, yet (provided one knows the rules) it conveys the same information. One need only apply the rules to derive the correct allophones.

Reference grammars (books addressed to linguists that offer a description of a language) often begin by setting out the phonemes and allophones. The first few transcriptions in a grammar are usually phonetic; then, once the allophonic rules have been duly set out, all the remaining transcriptions can safely be phonemic, without any loss of information.[3]

2.7 Phonological Rules

Generalizations about the patterning of allophones can be stated as phonological **rules**. For instance, to describe the patterning of [eɪ] and [ĕɪ] given above, one might write a rule like this:

/eɪ/ Shortening
The phoneme /eɪ/ *is realized as extra short when a voiceless consonant follows.*

We will refine our rules in many ways below, but this should get across the basic idea. The concept of rule is central to phonology; here are some elaborations.

First, rules are **language-specific**: the shortening of /eɪ/ (and, as it turns out, of other vowels) must be considered as a rule *of English*; it is not a universal rule, nor some kind of general principle of speech articulation. We know this because we have data from other languages that apparently lack any rule of this kind. For instance, neither Polish nor Saudi Arabic shortens vowels before voiceless consonants. The shortening rule of English is part of the phonological pattern of the English language, and must be learned in some form by children acquiring English.

[3] For convenience, authors of reference grammars usually take the further step of setting up a **practical orthography**, in which each phoneme is spelled using an ordinary letter or letter combination.

Second, rules are usually **productive** in the sense that they extend to novel cases. "*Vake*" and "*praig*" are not words of English, but if they become words, we can be confident that they will obey the rules and be pronounced [vĕɪk] and [pɹeɪg]. For more on productivity, see chapter 9.

Third, rules give rise to **well-formedness intuitions**. If a phonetician, or a speech synthesizer, were to create exceptions to the rule, English speakers sense the awkwardness of the result; thus [sĕɪv] and [seɪf] are inappropriate as natural renditions of *save* and *safe*. In other words, rule violations are sensed intuitively.

Fourth, phonological rules are **untaught**. Instead, they are learned intuitively by children from the ambient language data, using mechanisms that are as yet unknown. In this respect, phonological rules are very different from rules that are imparted by direct instruction, like (for example) the rules for traffic lights, or rules of **normative grammar** like "don't end a sentence with a preposition."

Lastly, phonological rules are evidently a form of **unconscious knowledge**. No matter how hard we try, we cannot access our phonological rules through introspection.

One shouldn't be surprised that this is so, because most of the computations that our brains carry out are similarly inaccessible to consciousness. For example, we can detect color constancy under variable conditions of light and shadow, or the direction of sound sources by the time delay between our ears. These processes involve rapid, automatic mental computations that cannot be intuited by the conscious mind as they occur. We consciously notice the *result* of such computations ("this object is uniformly red"; "a car is approaching from my left"), but not the way it is done. To understand such processes, cognitive scientists *infer* their mechanisms on the basis of observation, experimentation, and theorizing. No one bothers to ask people how they do these things, because people don't know.

Phonology is similar. When we speak, we automatically obey hundreds, perhaps thousands of phonological rules, but we can neither observe nor articulate what these rules are. Thus, when this book discusses "rules," what is meant is rules of the unconscious kind. We cannot learn about these processes through introspection, but must proceed indirectly, through data gathering, experiment, and construction of theories.

2.8 Formalizing Phonological Rules

We turn now to the problem of expressing the phonological rules precisely. In principle, we could just write all of the rules in prose – and indeed, this is usually done as backup, to help the reader understand the rules more easily. But in general, phonologists have found that use of a formal notation permits greater precision and clarity. Throughout this book, we will gradually accumulate more notational apparatus with this purpose in mind. The notations used here are drawn from the research literature in phonology; I have tried to limit myself to notations that would be widely recognized among phonologists.

2.8.1 Expressing environments

Let us start with some formalism for describing the environments where allophones occur. The symbol **slash**, "/", as used in phonology, means "in the environment." A **long underline** stands for where the allophone occurs relative to its neighbors. Thus the following expression:

$$/ \ \underline{\quad\quad} \ \theta$$

is to be read "in the environment 'before theta'", or, for short, just "before theta." If instead we had written "/ θ ___", it would be read "after theta."

In expressing the environment of an allophone, we often must specify not just a single sound like [θ], but a whole class of sounds. For example, the environment for [l̥͡l] (p. 25) includes the class of voiceless consonants. To describe such classes, we use **square brackets**, containing the particular phonetic properties – which, in the context of phonology, are called **features** – that designate the relevant class of sounds. (Features are covered in detail in chapter 4.) Thus, the following notation can be read "after a voiceless consonant":

$$/ \begin{bmatrix} \text{consonant} \\ \text{voiceless} \end{bmatrix} \underline{\quad\quad}$$

As can be seen, square brackets in phonology essentially mean "*and*"; hence $\begin{bmatrix} \text{consonant} \\ \text{voiceless} \end{bmatrix}$ means "a segment[4] which is a consonant *and* is voiceless."

The symbols "+" and "–" are used before feature names to mean that a segment either has, or does not have, the phonetic property that a feature designates. Thus, in more standard notation the environment just given would appear as:

$$/ \begin{bmatrix} \text{+consonant} \\ \text{–voice} \end{bmatrix} \underline{\quad\quad}$$

Where we want to refer to the beginnings and ends of grammatical constituents like words, we can use brackets, much as is done in the study of syntax and morphology. For example, the notation given below can be read "at the end of a word."

$$/ \ \underline{\quad\quad} \ ]_{\text{word}}$$

"At the beginning of a word" would be "$/ \ [_{\text{word}} \ \underline{\quad\quad}$."

4 As phonologists generally do, I will use the term "segment" to refer to a single speech sound.

2.8.2 Underlying representations and derivations

We turn next to the task of characterizing allophones as the variants of a single abstract phoneme. A widely adopted theoretical approach in phonology is to characterize the phoneme by setting up an abstract level of representation called the **underlying representation**, also called the **phonemic representation**, **underlying form**, or **base form**. The idea is that phonemes have an essential, characteristic form, which is altered in particular contexts by the rules of the phonology, applying in a derivation.

In a system of this kind, it is rational to adopt as the underlying representation of the phoneme its "elsewhere" allophone. Recall (p. 24) that the elsewhere allophone is the allophone that is not affiliated with any particular context, but rather is the sound that appears when no other special context is met. The phonological derivation starts out with the underlying form, and rules apply to derive from it the various allophones in their appropriate contexts. If no rule is applicable, the underlying form emerges unaltered as the output of the phonology.[5]

Using this approach, we can develop an explicit description of the system of allophones for the English phoneme /l/. We select /l/ as the underlying representation, and posit three rules, stated below in both formalism and prose.

/l/ Devoicing

/l/ → [l̥͡l] / $\begin{bmatrix} \text{+consonant} \\ \text{−voice} \end{bmatrix}$ ___

Partially devoice /l/ after a voiceless consonant.

/l/ Dentalization

/l/ → [ɫ̪] / ___ θ

/l/ *is rendered as velarized and dental before* [θ].

/l/ Velarization

/l/ → [ɫ] / ___ $]_{\text{word}}$

/l/ *is velarized word-finally.*

Along with the posited underlying forms and rules, an analysis of this type is usually illustrated by providing sample **derivations**. A derivation consists of a series of lines. The first contains the underlying representations of a set of forms, and the last contains the actual phonetic forms, which in this context are often

[5] A caution: I find that students sometimes spontaneously adopt a terminology in which the elsewhere allophone is termed "the phoneme" and the contextual allophones derived by rule are called the "allophones." This is perfectly coherent, but is not standard usage. Among phonologists, the elsewhere allophone counts as an allophone just like all the others, and the phoneme is a separate, abstract entity – it occurs at a deeper level of representation.

called **surface representations**. The intermediate lines show the application of the rules in order. Where a rule is inapplicable, the notation "—" is used to designate this.

Here is a derivation for four words containing /l/, specifically chosen to illustrate all of the rules above.

file	*slight*	*wealth*	*listen*	
/faɪl/	/slaɪt/	/wɛlθ/	/ˈlɪsən/	underlying forms
—	sl̥͡laɪt	—	—	/l/ Devoicing
—	—	wɛɫ̪θ	—	/l/ Dentalization
faɪɫ	—	—	—	/l/ Velarization
[ˈfaɪɫ]	[sl̥͡laɪt]	[ˈwɛɫ̪θ]	[ˈlɪsən]	surface forms

In this approach, we need not specify that the elsewhere allophone is [l]; that is simply the base form whenever none of the phonological rules happen to alter it. In other words, a phonological rule like "/l/ → [l] / elsewhere" is unnecessary.

The idea of a phonological derivation has over time proven fruitful. Often, the rules apply in an intricate, cross-cutting pattern, creating large numbers of allophones.[6] It also turns out (chapter 7) that, in many cases, the order in which the rules apply is crucial.

The derivations form the heart of a phonological discussion, and the reader of a phonological analysis is well advised to inspect rather than skim them.[7] In particular, in each case it is important to understand, by comparing the rule to the form, why the rule applied or did not apply. Thus, in reading the first line of the derivation above, you would want to reassure yourself that /l/ Devoicing did indeed apply correctly to *slight*, because /s/ is a member of the class of voiceless consonants; and similarly in all other cases.

2.9 Phonemes in Other Languages

A great number of languages have been subjected to phonemic analysis. This typological study has found great diversity, but also a certain degree of unity. As an example of the latter, there is a certain "core" set of speech sounds that tend to be employed as phonemes in a great number of languages. The following set, for example, constitutes all the sounds that occurred in at least 40 percent of the

[6] For instance, we can note that /l/ Dentalization probably doesn't need to carry out the full change /l/ → [ɫ̪]; rather, it should only make the change /l/ → [l̪], and a suitably generalized version of /l/ Velarization can handle that part of the change that velarizes the /l/.

[7] I find that in hard cases it is helpful to copy them down.

languages in Maddieson's (1984) survey of phonemic systems. It might be thought of as a "maximally ordinary" phonemic system.

p	t	tʃ	k	i		u
b	d	dʒ[8]	g	e		o
f	s	ʃ			a	
m	n		ŋ			
		l				
		ɾ				
w		j				

On the other hand, most phonemic inventories are not restricted to just these "core" sounds; more normally, an inventory will contain additional, more unusual sounds. For example, the typologically unusual aspects of English include /θ/, /ð/, the syllabic consonants, and the heavy representation of diphthongs in the vowel inventory. Unusual sounds often occur in multiple languages in the same geographic area; e.g., retroflexes in India and Australia, diphthongs in Northern Europe, and gliding tones in East Asia.

However, phonemic diversity extends beyond just phoneme inventories. A more subtle cross-linguistic difference concerns how the phonetic inventory of a language (that is, the complete collection of allophones) is organized into phonemes. In particular, a distinction that is phonemic (serves to distinguish words) in one language might be allophonic (predictably distributed) in another.

An example is found in the phonemic systems of English and Spanish. Spanish has many sounds that resemble sounds of English (we will consider only North American dialects of English here). In particular, English has a [t] and a tap [ɾ]. The [d] of Spanish is dental rather than alveolar, and there are also slight differences in the tap, but these are small enough to ignore for our purposes.

In North American English [ɾ] is (to a rough approximation) an allophone of the /t/ phoneme. The environment for [ɾ] is between two vowels of which the second is stressless. Words having /t/ that fit this environment, and which therefore show a tap, are given in the first column below.

	Phonemic	**Phonetic**		**Phonemic**	**Phonetic**
data	/ˈdeɪ**t**ə/	[ˈdeɪ**ɾ**ə]	*tan*	/ˈ**t**æn/	[ˈ**t**æn]
latter	/ˈlæ**t**ɚ/	[ˈlæ**ɾ**ɚ]	*attend*	/əˈ**t**ɛnd/	[əˈ**t**ɛnd]
eating	/ˈi**t**ɪŋ/	[ˈi**ɾ**ɪŋ]	*guilty*	/ˈgɪl**t**i/	[ˈgɪl**t**i]
Ottoman	/ˈɑ**t**əmən/	[ˈɑ**ɾ**əmən]	*cat*	/ˈkæ**t**/	[ˈkæ**t**]
rhetoric	/ˈɹɛ**t**əɹɪk/	[ˈɹɛ**ɾ**əɹɪk]	*active*	/ˈæk**t**ɪv/	[ˈæk**t**ɪv]
automatic	/ˌɔ**t**əˈmæ**t**ɪk/	[ˌɔ**ɾ**əˈmæ**ɾ**ɪk]	*Atkins*	/ˈæ**t**kɪnz/	[ˈæ**t**kɪnz]

8 [dʒ] actually falls somewhat short of 40%; it is included in the list above because of another strong cross-linguistic tendency, i.e. for the sounds to occur in complete, symmetrical series (e.g., voiced matching up with voiceless).

The second column combines other allophones of /t/, without narrowly transcribing their specific properties. In this column, we see where /t/ does **not** appear as the [ɾ] allophone: either because it fails to follow a syllabic sound (*tan*, *guilty*, *active*) or because it fails to precede a syllabic sound (*cat*, *Atkins*), or because the following syllabic sound is stressed (*attend*). But if all the right conditions are met simultaneously, as in the first column, we get [ɾ].

It can be seen that the difference between [t] and [ɾ] is not distinctive in English: the tap is a conditioned variant of the /t/ phoneme that shows up in a particular environment. The Tapping rule can be stated, as a first approximation, as follows:

Tapping

$$/\text{t}/ \quad \rightarrow \quad [\text{ɾ}]\ /\ [\text{+vowel}]\ \_\_\_ \begin{bmatrix} \text{+vowel} \\ \text{−stress} \end{bmatrix}$$

The phoneme /t/ is realized as [ɾ] *when it is preceded by a vowel and followed by a stressless vowel.*

Here are derivations:

data	*tan*	*attend*	*cat*	*guilty*	
/ˈdeɪ**t**ə/	/ˈ**t**æn/	/əˈ**t**ɛnd/	/ˈkæ**t**/	/ˈgɪl**t**i/	underlying forms
ɾ	—	—	—	—	Tapping
[ˈdeɪɾə]	[ˈtæn]	[əˈtɛnd]	[ˈkæt]	[ˈgɪlti]	surface forms

In Spanish, /t/ and /ɾ/ are separate phonemes, as is demonstrated by minimal pairs such as the following:

[ˈpita]	‘century plant’
[ˈpiɾa]	‘funeral pyre’

As with the minimal pairs given for English above, this one demonstrates that for Spanish, the difference between [t] and [ɾ] signals a difference in meaning. That is to say, [t] and [ɾ] are in contrast, and are separate phonemes, /t/ vs. /ɾ/.

Comparing English and Spanish, we see that the [t] vs. [ɾ] difference is allophonic (non-distinctive) for English, but phonemic (distinctive) for Spanish. Thus, in this area, the two languages are *phonetically similar but phonologically different*.

Here is a similar case. Both English and Spanish have a [d] and a [ð] (the voiced dental fricative). In English, we know that the two sounds are separate phonemes, because minimal pairs exist:

die	[**d**aɪ]	vs.	*thy*	[**ð**aɪ]
bayed	[beɪ**d**]	vs.	*bathe*	[beɪ**ð**]
den	[**d**ɛn]	vs.	*then*	[**ð**ɛn]

But in Spanish, there are no such pairs. Furthermore, by looking at Spanish data one can determine that [d] and [ð] are allophonic variants:

[daðo]	'given'
[deðo]	'finger'
[usteð]	'you (polite)'
[donde]	'where'
[de ðonde]	'from where'

These and other data indicate that [ð] occurs only after a vowel, while [d] is the elsewhere allophone, occurring after consonants and initially. Thus [ð] and [d] are allophones of the same phoneme.

We can set up the following phonological analysis for the sounds of Spanish discussed so far.

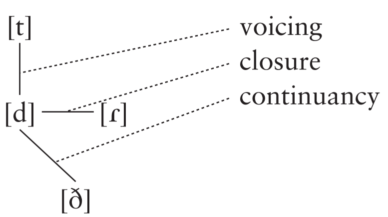
Phonemes: /t/, /d/, /ɾ/

Phonological rule: **/d/ Spirantization**
/d/ → [ð] / [+vowel] ___
The phoneme /d/ *is realized as* [ð] *when it follows a vowel.*

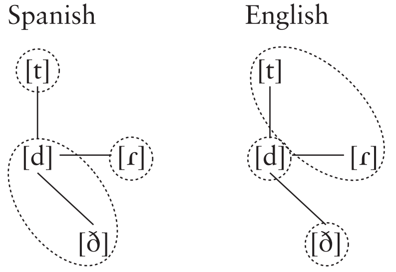
Derivations:	'given'	'you'	'where'	
	/dado/	/usted/	/donde/	underlying forms
	ð	ð	—	/d/ Spirantization
	[daðo]	[usteð]	[donde]	surface forms

Regarding the name of the rule, **spirantization** is the conventional term in phonology for rules that convert stops to fricatives; such rules are common. "Spirant" is a mostly obsolete synonym for "fricative."

The differences in phonological organization between English and Spanish reflect a different division of phonetic space. Suppose we construe phonetic space as made up of multiple dimensions. We place [d] at the center of this space, and in different directions show [ð] as differing from [d] minimally in its fricative character ("continuancy"); [ɾ] differing from [d] in having short, weak closure; and [t] differing minimally from [d] in voicing:



The phones of this phonetic space are grouped into phonemes differently by Spanish and English, as shown below:



The dotted lines surround groups of sounds that fail to contrast, and thus form single phonemes in the language in question. English has /d/, /ð/, and /t/, with the latter having two allophones [t] and [ɾ]. Spanish has /t/, /ɾ/, and /d/, with the latter having two allophones [d] and [ð]. The chart shows that the sound systems of languages can differ in their phonological organization, as well as in the sounds that they contain. In principle, we could imagine two languages that had exactly the same sounds, but a radically different phonological organization. This would happen if the two languages selected different phonetic distinctions to be contrastive vs. non-contrastive. Using the phonemic method, we would analyze such languages as having the same set of sounds, grouped into phonemes in two different ways.

2.10 Phonemicization

Phonemicization is the body of knowledge and techniques that can be used to work out the phonemic system of a language. The method described below has been in existence for several decades and has been used on many languages. Of course, no recipe in linguistics provides certain results, and later on in this text we will see cases where the method falls short. But it is usually the starting point for working out the phonology of a language.

A really solid phonemicization is often the result of years of hard work, carried out by linguists with good ears and extensive experience with the target language. The reason that phonemicization takes so long is that the first linguist or team of linguists to encounter a language will quite often fail to notice a difficult-to-hear contrast. Another factor is that certain phonemes might be rare, and will be encountered only after the linguist has collected a large vocabulary.

2.10.1 Minimal pairs

By far the most effective method in phonemicization is to look for **minimal pairs**, which (to review) are defined as two different words that differ in exactly one sound in the same location. Some examples: *sip* [sɪp] and *zip* [zɪp] in English form a minimal pair for the phonemes /s/ and /z/; *sill* [sɪl] and *zeal* [zil] are not a minimal pair, because they differ in two locations; *seal* [sil] and *eels* [ilz] are not a minimal pair because the /s/ and /z/ occur in different places. Two sounds that appear in a minimal pair are almost always distinct phonemes.[9]

The **absence** of a minimal pair does not prove much. Often, a language will lack minimal pairs for a pair of relatively rare phonemes simply by accident. A method for dealing with such cases is given in the next section.

As noted earlier, minimal pairs generalize to minimal triplets, quadruplets, and so on. Often, selecting a good "frame" or phonological context will make it possible to justify quite a bit of the phonemic inventory of a language. A notation that is commonly used for such frames is to place the environment sounds on either side of an underlined blank, which represents the sound being manipulated in the pair, quadruplet, etc. Thus for American English vowels, the frame /h __ d/ gets all but /ɔɪ/, though admittedly some of the words are a bit forced:[10]

heed	[hid]			*who'd*	[hud]
hid	[hɪd]			*hood*	[hʊd]
hayed	[heɪd]			*hoed*	[hoʊd]
head	[hɛd]	*HUD*	[hʌd]		
had	[hæd]	*hod*	[hɑd]	*hawed*	[hɔd]
hide	[haɪd]	*how'd*	[haʊd]		
heard	[hɚd]				

For the missing /ɔɪ/, it is easy to imagine that "*hoid*" *could* be a word; its absence from English is essentially an accident.

2.10.2 Near-minimal pairs

There are cases in which it is impossible to find minimal pairs for a phoneme. This probably occurs more frequently in languages with long words and large phoneme inventories. In English there appear to be cases where, at least for some idiolects, a minimal pair cannot be found.[11] Conducting a search in an electronic dictionary for minimal pairs for English /ð/ and /ʒ/, I found that it included only three plausible candidates:

bathe	[ˈbeɪð]	vs.	*beige*	[ˈbeɪʒ]
leather	[ˈlɛðɚ]	vs.	*leisure*	[ˈlɛʒɚ]
seethe	[ˈsið]	vs.	*siege*	[ˈsiʒ]

[9] The exceptions are discussed below in §7.1.1 and §10.3.

[10] *hayed* 'made hay', *HUD* 'colloquial abbreviation for United States Department of Housing and Urban Development.'

[11] An **idiolect** is a language as it is learned and internalized by a single individual. A dialect is a collection of closely similar idiolects, characterizable by region or social class. I refer to idiolects here because I doubt that there is any English dialect whose speakers uniformly lack minimal pairs of the kind under discussion.

However, for all three [ʒ] words, the pronunciation varies by dialect: there are many speakers who have [ˈbeɪd͡ʒ] for *beige*, [ˈliʒɚ] or [ˈlɛʒʊɹ] for *leisure*, and [ˈsid͡ʒ] for *siege*. For such a speaker, there are presumably no minimal pairs for [ð] vs. [ʒ].

Despite this, it is impossible that [ð] and [ʒ] could be allophones of the same phoneme, even in such a dialect. If they were allophones, we would expect that we could locate the **rules** that determine which allophone occurs where. But a moment's reflection will show that there could be no such rules.

This is shown by the existence of **near-minimal pairs**, which can be defined as pairs which would be minimal except for some evidently irrelevant difference. Here are some near-minimal pairs for /ð/ vs. /ʒ/:

tether	[ˈtɛðɚ]	vs.	*pleasure*	[ˈplɛʒɚ]
		or	*measure*	[ˈmɛʒɚ]
neither	[ˈniðɚ]	vs.	*seizure*	[ˈsiʒɚ]
lather	[ˈlæðɚ]	vs.	*azure*	[ˈæʒɚ]
heathen	[ˈhiðən]	vs.	*adhesion*	[ədˈhiʒən]
smoothen	[ˈsmuðən]	vs.	*illusion*	[ɪˈluʒən]
		or	*intrusion*	[ɪnˈtɹuʒən]
		or	*fusion*	[ˈfjuʒən]

This list shows that the phonetic environment has nothing to do with whether [ð] or [ʒ] occurs – there is no *consistent* factor that could determine which segment appears. Any effort to find the rules that determine the appearance of [ð] vs. [ʒ] would have to make use of a completely arbitrary collection of "environments" for these phones. If the rules cannot be found, then an analysis that claims that [ð] and [ʒ] are allophones cannot be justified.

It is also easy to imagine that if a new word came into English that created a true minimal pair (say, '*hesion*' to go with *heathen*), such a word would readily be accepted. It is logical, then, to assume that /ð/ and /ʒ/ are separate phonemes, and that (for some speakers) no minimal pairs happen to be available. The near-minimal pairs suffice to show this.

Plainly, the near-minimal pair method of establishing phonemes requires more work than minimal pairs do: it is the accumulation of forms, and the ruling out of all reasonable hypotheses concerning allophone environments, that ultimately permits near-minimal pairs to be used as evidence.

2.10.3 Using local environments to establish complementary distribution

The methods of minimal and near-minimal pairs are used to establish that two sounds belong to separate phonemes. For establishing that two sounds are in the same phoneme, we need to establish that they are in complementary distribution, and therefore we need to find the environments in which they occur. For this purpose, it is often useful to follow the method of **compiling local environments**, illustrated below.

The language we will examine is Maasai (Nilotic, spoken in Kenya and Tanzania), and our focus is solely on the following set of sounds: [p, t, k, b, d, g, β, ð, ɣ]. The last three of these are voiced fricatives: [β] is bilabial, [ð] dental, and [ɣ] velar. Below are 63 words containing these sounds.

Maasai data

1	[ailap]	'to hate'
2	[aret]	'to help'
3	[arup]	'to heap up'
4	[asip]	'to speak truly'
5	[ɓarːiɣoi]	'reddish brown'
6	[ɓaða]	'dangerous'
7	[ɗalut]	'mischievous'
8	[ɗiɣai]	'elsewhere'
9	[ɗorːop]	'short'
10	[emɓiðir]	'female wart hog'
11	[emaɲaða]	'warriors' village'
12	[embiʄan]	'bravery'
13	[emburuo]	'smoke'
14	[enɗaraða]	'thunder'
15	[enɗuβai]	'sisal'
16	[eŋɠirut]	'silent-feminine'
17	[eŋɠoː]	'small chest'
18	[enaiβoʃa]	'Naivasha Lake'
19	[endaːraða]	'fight each other'
20	[endorop]	'bribe him'
21	[endulelei]	'sodom apple'
22	[enduβeiðai]	'Taveta woman'
23	[eŋgamaniɣi]	'name of age-set'
24	[eŋgila]	'garment-diminutive'
25	[eŋgiruðoðo]	'fright'
26	[eŋgoː]	'advise him'
27	[eŋoɣi]	'sin'
28	[ilarak]	'murderers'
29	[ilkeːk]	'trees'
30	[ilpaβit]	'hairs'
31	[iltoːi]	'barrel'
32	[imɓok]	'you detain'
33	[imbala]	'papers'
34	[imbaɣiβak]	'you are restless'
35	[imbok]	'you clean ceremonially'
36	[indai]	'you-plural'
37	[ijːoːk]	'we'
38	[kaɣe]	'but'
39	[keɗianje]	'left side'
40	[keβer]	'heaven'
41	[kiɓiroðo]	'stunted'
42	[koɣoː]	'grandmother'
43	[olɗiret]	'pack saddle'
44	[olɗuɣa]	'shop'
45	[olɠilaða]	'room'
46	[olʄiβet]	'stake'
47	[olkila]	'garment'
48	[olkiɣuei]	'thorn'
49	[olporːor]	'age set'
50	[olpul]	'slaughtering place'
51	[olpurɗa]	'meat preserved in fat'
52	[olpurkel]	'dry steppes'
53	[oltaː]	'lamp'
54	[oltulet]	'gourd in natural state'
55	[oltuli]	'buttock'
56	[paɗan]	'skilled in shooting'
57	[poɣira]	'all'
58	[pus]	'light colored'
59	[sarkin]	'intermarriage taboo'
60	[taruɓini]	'binoculars'
61	[tasat]	'disabled'
62	[tisila]	'sift it'
63	[tiʃila]	'scrutinize it'

The first thing to notice about the data is that they include an additional series of stops: /ɓ ɗ ʄ ɠ/. These are voiced implosives, made by lowering the larynx to form a slight vacuum in the mouth during closure. The implosives form a separate series of phonemes in Maasai, as can be shown by minimal and near-minimal pairs such as the following:

35.	[im**b**ok]	'you clean ceremonially'
vs. 32.	[im**ɓ**ok]	'you detain'
7.	[**ɗ**alut]	'mischievous'
vs. 61.	[**t**asat]	'disabled'
26.	[eŋ**g**oː]	'advise him'
vs. 17.	[eŋ**ɠ**oː]	'small chest'
41.	[ki**ɓ**iroðo]	'stunted'
vs. 40.	[ke**β**er]	'heaven'

Having established this, we will ignore the implosives henceforth.

The method of compiling local environments works as follows: for each sound, we construct a list of all its appearances, each time including the preceding segment, if any, and the following segment, if any. For example, word #5, [ɓarːiɣoi] 'reddish brown' contains the target sound [ɣ]. This sound is preceded by [i] and followed by [o]. Thus, we add to our chart the following entry, in a column headed [ɣ]:

[ɣ]
/ i ___ o (5)

This chart entry may be read "[ɣ] occurs where preceded by [i] and followed by [o], in example (5)."

Where the target sound is the initial or final segment in the word, one includes in the environment a bracket of the type $]_{\text{word}}$ to designate this environment:

[k]
/ oː ___ $]_{\text{word}}$ (37)

This expression may be read "[k] occurs where preceded by [oː] and word-final."

One then continues through the whole set of data in this way. If this is done for the **velar** sounds only, one gets the following:

[k]		[g]		[ɣ]	
/ $[_{\text{word}}$ ___ a	(38)	/ ŋ ___ a	(23)	/ a ___ e	(38)
/ $[_{\text{word}}$ ___ e	(39, 40)	/ ŋ ___ i	(24, 25)	/ a ___ i	(34)
/ $[_{\text{word}}$ ___ i	(41)	/ ŋ ___ o	(26)	/ i ___ a	(8)
/ $[_{\text{word}}$ ___ o	(42)			/ i ___ i	(23)
/ l ___ e	(29)			/ i ___ o	(5)
/ l ___ i	(47, 48)			/ i ___ u	(48)
/ r ___ e	(52)			/ o ___ i	(27, 57)
/ r ___ i	(59)			/ o ___ oː	(42)
/ a ___ $]_{\text{word}}$	(28, 34)			/ u ___ a	(44)
/ eː ___ $]_{\text{word}}$	(29)				
/ o ___ $]_{\text{word}}$	(32, 35)				
/ oː ___ $]_{\text{word}}$	(37)				

At this point, one inspects the data in hopes of locating general patterns. For these data, notice that [g] may occur only when the sound [ŋ] immediately precedes it. Further, and crucially, the sounds [k] and [ɣ] are **never** preceded by [ŋ] – which makes the distribution complementary. It thus looks likely that [g] is just one allophone of a phoneme, because it has such a highly restricted distribution. The preceding [ŋ] is likely to be the context that requires this allophone.

Inspecting the third column, we see another particular property: all cases of [ɣ] are surrounded by vowels. As before, this is not the case with the other candidate phones. The pattern suggests that [ɣ] is another allophone of the phoneme that includes [g].

Inspection of the [k] column shows no particularly interesting property: [k] may occur initially, after [r] or [l], and in final position. The only really important property here is that these various environments do *not* include the environments for [ɣ] or [g]. This makes [k] a good candidate for being an "elsewhere" allophone, in the sense described on p. 24 above.

We have established, then, that [k], [ɣ], and [g] are in complementary distribution: none occurs when any of the others may occur. The environments are shown below.

[g]	/ ŋ ___	
[ɣ]	/ V ___ V	where V stands for any vowel
[k]	/ elsewhere	

It is reasonable to suppose that [k], as the elsewhere allophone, is the normal, unperturbed member of the phoneme, which we set up as the underlying representation. [g] and [ɣ] are particular allophones resulting from phonological rules applying in particular environments. Note finally that, once we write the rules, the changes that they will carry out are not drastic: [k] and [g] differ only in voicing, while [k] and [ɣ] differ only in voicing and manner. This gives some additional plausibility to the idea that these sounds are related by rule.

Pursuing this, we can state the phonological analysis of these sounds as follows. First, /k/ is assumed to be a phoneme of Maasai, which undergoes the following two phonological rules.

/k/ Spirantization
k → ɣ / [+vowel] ___ [+vowel]
/k/ *is realized as* [ɣ] *between vowels.*

Postnasal Voicing
k → g / ŋ ___
/k/ *is realized as [g] after* [ŋ].

Sample phonological derivations for three representative words of Maasai are as follows:

'grandmother'	'garment-dim.'	'trees'	
/kokoː/	/eŋkila/	/ilkeːk/	underlying forms
ɣ	—	—	/k/ Spirantization
—	g	—	Postnasal Voicing
[koɣoː]	[eŋgila]	[ilkeːk]	surface forms

It should be clear why the method of collecting local environments was useful here: as it turned out, the environments for the rules were in fact local, involving adjacent segments. While this is not true of all phonological rules,[12] it is common enough to make the strategy worthwhile.

Plainly, the procedure is tedious. It is possible, for many people and in many cases, to skip steps. If you have a knack for this, phoneme problems can be solved by inspection, without the tedious charting of all environments.

Another asset in solving such problems is experience. The same rules often show up in many different languages, so someone who has examined extensive phonological data before has a leg up in solving new problems. In the present case, we can note some languages that realize /k/ as [ɣ] between vowels: Taiwanese, Ewe (Ghana), and Tümpisa Shoshone (Death Valley, California). Languages that realize [k] as [g] after a nasal include Modern Greek, Leurbost Gaelic (Scotland), and Waorani (Amazon basin, Peru). The questions of *why* the same rules recur in many different languages is one of the outstanding issues in phonological theory.

[12] The primary exceptions are vowel-to-vowel rules (example on p. 154), stress rules (treated in ch. 14), and the occasional long-distance consonant-to-consonant rule (see p. 84).

2.10.4 More Maasai: natural classes

We have not yet considered six of the nine Maasai sounds we set out to analyze, namely [p, b, β] and [t, ð, d]. Before proceeding, it is useful to arrange the relevant sounds into phonetic charts. Ideally, we would do this for all of the sounds of Maasai, but for present purposes the following will suffice:

	Bilabial	*Dental*	*Velar*
voiceless stops	p	t	k
plain voiced stops	b	d	g
voiced implosive stops	ɓ	ɗ	ɠ
voiced fricatives	β	ð	ɣ
voiced nasals	m	n	ŋ

If we sort out the target sounds in the way we did before, we will get the following:

[p]		[b]		[β]	
/ [$_{word}$ ___ a	(56)	/ m ___ a	(33, 34)	/ a ___ i	(30)
/ [$_{word}$ ___ o	(57)	/ m ___ i	(12)	/ e ___ e	(40)
/ [$_{word}$ ___ u	(58)	/ m ___ o	(35)	/ i ___ a	(34)
/ l ___ a	(30)	/ m ___ u	(13)	/ i ___ e	(46)
/ l ___ o	(49)			/ i ___ o	(18)
/ l ___ u	(50, 51, 52)			/ u ___ a	(15)
/ a ___]$_{word}$	(1)			/ u ___ e	(22)
/ i ___]$_{word}$	(4)				
/ o ___]$_{word}$	(9, 20)				
/ u ___]$_{word}$	(3)				

[t]		[d]		[ð]	
/ [$_{word}$ ___ a	(60, 61)	/ n ___ aː	(19)	/ a ___ a	(6, 11, 14, 19, 45)
/ [$_{word}$ ___ i	(62, 63)	/ n ___ a	(36)	/ i ___ a	(22)
/ l ___ aː	(53)	/ n ___ o	(20)	/ i ___ i	(10)
/ l ___ oː	(31)	/ n ___ u	(21, 22)	/ o ___ o	(25, 41)
/ l ___ u	(54, 55)			/ u ___ o	(25)
/ a ___]$_{word}$	(61)				
/ e ___]$_{word}$	(2, 43, 46, 54)				
/ i ___]$_{word}$	(30)				
/ u ___]$_{word}$	(7, 16)				

If you consider both the phonetic chart and the list of environments, you can see that the distribution of the bilabial and dental sounds is in complete parallel with the velars: voiced stops appear after nasal consonants, voiced fricatives occur between vowels, and voiceless stops occur elsewhere.

Thus, although we are dealing with three phonemes and nine allophones, we do not need a large number of rules to cover the data. Rather, we can use features to write general rules that cover all three phonemes at once. The specific analysis sets up the three phonemes /p/, /t/, and /k/ and posits two generalized phonological rules.

Spirantization

$$\begin{bmatrix} \text{+stop} \\ \text{–voice} \end{bmatrix} \rightarrow \begin{bmatrix} \text{+voice} \\ \text{–stop} \\ \text{+fricative} \end{bmatrix} \ / \ [\text{+vowel}] \ \_\_\_ \ [\text{+vowel}]$$

A voiceless stop is realized as the corresponding voiced fricative when surrounded by vowels.

Postnasal Voicing

[+stop] → [+voice] / [+nasal] ___

A voiceless stop is realized as the corresponding voiced stop when it follows a nasal consonant.

For this approach to work, we need to be explicit about how features are used in rules. If a feature occurs on the right side of the arrow, that feature is changed, whenever the rule applies. But *all other features are assumed to remain unaltered*. Thus, if we are considering a sequence like /mp/ and apply Postnasal Voicing (as in #33, /impala/ → [im**b**ala]), the [–voice] of the /p/ is changed to [+voice], so that /p/ is altered to [b]. But the features [+bilabial] and [+stop] remain unaltered. In this way, we can express rules that alter whole classes of segments (such as all the voiceless stops) in parallel. The features therefore permit a simpler and more general analysis than would be available if all the allophones of each phoneme were derived separately.

The fact that the stop phonemes of Maasai vary in parallel fashion is not an accident. The same phenomenon shows up in a great number of languages. Here are two examples we've already covered of how rules apply to classes of sounds.

Vowel Shortening in English: The shortening of /eɪ/ to [ĕɪ] before voiceless consonants in English (p. 26) is not unique to /eɪ/: all vowels of English are shortened in this environment. Examples: *coat* [kŏʊt] vs. *code* [koʊd], *lap* [lǽp] vs. *lab* [læb], etc.

Spirantization in Spanish: Spanish not only has [ð] as a post-vowel allophone of /d/ (p. 33), but also [β] as a post-vowel allophone of /b/ and [ɣ] as a post-vowel allophone of /g/. In other words, all voiced stops are converted to the corresponding fricatives in the post-vowel environment. Examples: /ˈlobo/ [ˈloβo] 'wolf', /ˈlago/ [ˈlaɣo] 'lake'.

The general lesson that we learn from these examples (and countless others) is this: *phonological rules are based on phonetic features*. This general principle has three specific subcases.

First, the *set of sounds a rule applies to* is normally a set of sounds that share a particular phonetic feature or set of features. For example, the Spirantization rule of Spanish applies to all and only the voiced stops, characterized as [+stop, +voice].

Second, rules often change only *one or two features* of a sound, rather than making massive alterations. For example, the rules for Maasai alter only voicing and the stop/fricative distinction.

Lastly, the *sounds appearing in the environment of a rule* are almost always a set of sounds that share a particular phonetic feature or features. For example, the rule of English that shortens vowels applies before the complete set of consonants in English that are [–voice].

A **natural class** of sounds is defined as any complete set of sounds in a given language that share the same value for a feature or set of features. For example, /m/, /n/, and /ŋ/ in Maasai and in English form a natural class because they constitute the complete set of sounds that share the feature [+nasal]. Likewise, /p/, /t/, and /k/ form a natural class in Maasai and in English because they constitute all the [+stop, –voiced] sounds of the language.

It can be noted that the natural class defined by a particular feature combination will vary from language to language, simply because different languages have different inventories of sounds. Thus, in English [p t k] form the natural class of voiceless stops ([+stop, –voice]). Yet [p t k] are not a natural class in Persian (Farsi), since Persian contains a fourth voiceless stop, uvular [q]. For Persian, [+stop, –voice] is a natural class, but consists instead of the sounds [p t k q].

To reiterate the point made above with the novel terminology: in most instances, the segments that undergo a rule or appear in the environment of a rule form a natural class in the language in question.

Exercises

1 /ɹ/ in American English

This is a simple allophone problem, to be solved like the Maasai allophone problem in §2.10.3 above. The focus sounds are the voiced alveolar central approximant [ɹ], and the (slightly) rounded voiced alveolar central approximant [ɹʷ].

migrants	['maɪgɹʷənts]	*Homeric*	[hoʊ'mɛɹʷɪk]
or	['ɔɹ]	*trek*	['tɹʷɛk]
from	['fɹʷʌm]	*debriefed*	[di'bɹʷift]
shire	['ʃaɪɹ]	*reply*	[ɹʷi'plaɪ]
tripling	['tɹʷɪplɪŋ]	*Iraqi*	[ɪ'ɹʷɑki]
metaphor	['mɛtəˌfɔɹ]	*preys*	['pɹʷeɪz]
iridium	[ɪ'ɹʷɪdiəm]	*ranted*	['ɹʷæntəd]
proclivities	[pɹʷoʊ'klɪvəɾiz]	*crucible*	['kɹʷusəbəl]
romancing	[ɹʷoʊ'mænsɪŋ]	*indiscriminately*	[ˌɪndəs'kɹʷɪmənətli]
February	['fɛbjuɛɹʷi]	*fear*	['fɪɹ]
dwarfing	['dwɔɹfɪŋ]	*dreadful*	['dɹʷɛdfəl]
assure	[ə'ʃuɹ]	*feldspar*	['fɛldspɑɹ]

2 Lango phonemes

Lango is a Nilotic language spoken in Uganda.

a. Make a phonetic chart of all the consonants in the data below (columns: place of articulation; rows: manner of articulation, voicing, and length).
b. This problem deals just with the sounds [p, pp, ɸ, t, tt, ɾ̥, t͡ɕ, tt͡ɕ, ɕ, k, kk, x]. Collect local environments for these sounds only, following the method given in this chapter.
c. The sounds [p, pp, ɸ, t, tt, ɾ̥, t͡ɕ, tt͡ɕ, ɕ, k, kk, x] may be grouped into eight phonemes. List the eight phonemes and their allophones. State the environments where the allophones occur. You may use "elsewhere" to simplify your presentation.
d. State in words the phonological rules that determine the allophones. There is a major ambiguity in determining what is an allophone of what. Figure out this ambiguity, and state analyses for both possibilities.
e. The word for 'lazy' is [ɲàp], with a [p]. The word for 'laziness' is [ɲáɸô], with a [ɸ]. Explain how this bears on the ambiguity noted in the previous question.

Phonetic symbols:

- [á] marks High tone, [à] marks Low, [â] marks Falling.
- [t͡ɕ] and [d͡ʑ] are alveolopalatal affricates, [ɕ] is an alveolopalatal fricative.
- [ɾ̥] is a voiceless tap.
- Consonants transcribed as double are simply held longer; they are not "rearticulated." Think of them as single long consonants.

1	[pì]	‘because of’
2	[kèt͡ɕ]	‘hunger’
3	[tɔ́ŋ]	‘spear’
4	[bútt͡ɕó]	‘to yell at’
5	[t͡ɕɔ̀ː]	‘men’
6	[ʔɔ̀t]	‘house’
7	[dɔ̀ttɔ̀]	‘to suck’
8	[pə̀ppì]	‘fathers’
9	[pójó]	‘to remember’
10	[ljèt]	‘hot’
11	[bókkó]	‘to make red’
12	[jútt͡ɕú]	‘to throw’
13	[èŋə́ɾ̥ó]	‘lion’
14	[ókkɔ́]	‘completely’
15	[déɸô]	‘to collect’
16	[dɛ̀k]	‘stew’
17	[t͡ɕùɸâ]	‘bottle’
18	[gwɛ̀k]	‘gazelle’
19	[kókkó]	‘to cry’
20	[ɲáɸô]	‘laziness’
21	[ɾɛ́t͡ɕ]	‘fish’
22	[bóɾ̥ə́]	‘to me’
23	[dìppó]	‘to smash’
24	[dwéɾ̥ê]	‘months’
25	[kóddó]	‘to blow’
26	[t͡ɕín]	‘intestines’
27	[gíɾ̥é]	‘really’
28	[lòɕə̀]	‘man’
29	[kwə̀ɕê]	‘leopards’
30	[kál]	‘millet’
31	[màɕê]	‘fires’
32	[àbíɕɛ̀l]	‘six’
33	[dáxô]	‘woman’
34	[t͡ɕùt͡ɕ]	‘pitch black’
35	[tódd͡ʑó]	‘to beat up’
36	[wókkí]	‘a few minutes ago’
37	[dìə̀xə̀]	‘wet’
38	[máxât͡ɕ]	‘scissors’
39	[pé]	‘snow, hail’
40	[kɔ́ppɔ̀]	‘cup’
41	[pàtt͡ɕó]	‘to peel’
42	[pámmà]	‘cotton’
43	[mɔ̀ɾ̥ɔ̀xà]	‘car’
44	[bə̀p]	‘to deflate’
45	[lwɪ̀ttɛ̂]	‘to sneak’
46	[ɲàp]	‘lazy’
47	[bwɔ̀ttɔ̀]	‘to retort insultingly’
48	[tèttó]	‘to forge’
49	[t͡ɕàmmó]	‘to eat’
50	[tɔ̀p]	‘to spoil’
51	[t͡ɕɔ́k]	‘near’
52	[pàɸó]	‘father’
53	[ŋwɛ̀tt͡ɕó]	‘to run from’
54	[bót]	‘to’
55	[dɛ̀ppó]	‘to collect’
56	[gɔ̀t]	‘mountain’
57	[jìt͡ɕ]	‘belly’
58	[bìttó]	‘to unshell’
59	[dɔ̀k]	‘to go back’
60	[kòp]	‘matter’
61	[tîn]	‘today’
62	[kít]	‘kind’
63	[àkká]	‘purposely’
64	[t͡ɕàk]	‘milk’

Further reading

The opening of this chapter states that the central subject matter of phonology is *sound patterns* in language. This invokes two important early phonological works. Edward Sapir’s “Sound patterns in language” (1925; *Language* 1: 37–51) was the first work to point out that two languages could have phonetically identical inventories but quite different phonologies (see §2.9 above). *The Sound Pattern of English*, by Noam Chomsky and Morris Halle (1968, Harper and Row) is by consensus the most important single work in phonological theory. Many of the ideas given in this text first appeared there.

The systematization of a procedure for finding the phonemes of a language was one of the major accomplishments of the so-called "American structuralist" school of linguistics, which flourished from approximately the 1920s to the 1950s. A fine presentation of the method of phonemicization by a member of this school may be found in H. A. Gleason's *An Introduction to Descriptive Linguistics* (1961, Holt, Rinehart and Winston). Two works that are widely considered to be gems of American structuralism are *Language* by Leonard Bloomfield (1933, reprinted 1984, University of Chicago Press) and *Language: An Introduction to the Study of Speech* by Edward Sapir (1921, Harcourt Brace; now on line at www.bartleby.com/186/).

The maximum and minimum phoneme counts in §2.2 are taken from Ian Maddieson's *Patterns of Sounds* (1984, Cambridge University Press), a very useful survey of several hundred phoneme inventories.

The point that shortening of vowels before voiceless consonants is a rule specific to particular languages is argued for in Patricia Keating, "Universal phonetics and the organization of grammars," in Victoria Fromkin, ed., *Phonetic Linguistics* (1985, Academic Press).

Maasai phonemes: Archibald N. Tucker and J. Tompo Ole Mpaayei, *A Maasai Grammar with Vocabulary* (1955, Longman, Green).