CHAPTER 3
Allophonic relations

PREVIEW

This chapter begins the analysis of phonological processes. You will:

- learn of predictable variants of basic sounds in English
- learn about the concepts "phoneme" and "allophone"
- discover that similar relations between sounds exist in other languages
- begin to learn the general technique for inducing phonological rules from data that come from a language which you do not know
- be introduced to writing phonological rules

KEY TERMS

allophone

phoneme

complementary distribution

contrast

distinctive

As explained in the preceding chapters, the focus of phonology is the mental rules which govern the symbol choices determining pronunciation of words in a given language. In order to pronounce "scheme" in English, you have to know how to articulate the four-segment sequence [skim], according to the physical rules of English phonetic implementation. Likewise to pronounce "scream", slightly different physical rules of implementation must be followed in producing [skɹʷim], in that the lips must start protruding for *r* during the production of *s* (see Ch. 1). The result is that lip-protrusion changes continuously over time within the production of *s*, increasing into *k* before *r*, which is, at least in that dialect, produced with substantial lip-protrusion.

Certain facts about pronunciation simply cannot be predicted by rule, for example the fact that in English the word *sick* is pronounced [sɪk] and *sip* is pronounced [sɪp]. A fundamental component of a language is a lexicon, which is a list of words (or morphemes – parts of words), a list that must provide any information which cannot be predicted by rules of the language. The "basic segments" of which a word is composed are an important part of the lexicon. Some aspects of the pronunciation of words can be predicted on the basis of existing information, either coming from the lexicon or being a product of the rule system. For example, in the word *tick* the initial voiceless consonant *t* is phonetically aspirated, being pronounced as [t^hɪk]. This aspiration can be demonstrated visually by dangling a tissue in front of the mouth when saying the word. Notice that when you pronounce *t*, the tissue is blown forward. In comparison, *t* in the word *stick* is not aspirated (thus, the tissue is not blown forward), and this word is transcribed as [stɪk]. This fact can be predicted by rule, and we now consider how this prediction can be encoded by a phonological rule, one which changes a segment from one distinctive sound category to another. But first we must show that rules predicting such information exist, and are part of phonology.

3.1 English consonantal allophones

Let us start with a simple question about English consonants: what are the consonants of English? Uncontroversially, English has a consonant *s*, which occurs frequently. Also uncontroversially, English does not have the pharyngeal fricative ʕ, the rounded uvular stop q^w, or the lateral click ǁ. These sounds do not occur in English, at least as long as the person is speaking English. A few individuals may be able to code-switch and utter words like Arabic [ʕali:] (a name, Ali), or refer to the language Xhosa as [ǁosa] or [$ǁ^h$osa], but usually in English people say [ali:] and [k^hoʊsə] or [hoʊsə], because English does not have the sounds ʕ or ǁ. Now, does English have the consonants *d, t* and t^h? Yes and no, depending on criteria. Uncontroversially, English has both *t* and *d*, and the selection of *t* versus *d* can constitute the sole difference between many different words in English. Such words, where two words are differentiated exclusively by a choice between one of two segments, are referred to as **minimal pairs**.

(1)	[d]	[t]	[d]	[t]
	dire	**t**ire	**d**o	**t**wo
	Dick	**t**ick	ha**d**	ha**t**
	sai**d**	se**t**	ben**d**	ben**t**

A minimal pair is a pair of utterances transcribed phonetically (as we have done in Chapter 2), where the utterances are different linguistic forms (usually "different words"), and the transcriptions are identical except for the choice of one sound – [d] versus [t], for example. Given the phonetic transcriptions [dajɹ] and [tajɹ], we have a minimal pair. It is a fundamental principle of linguistic analysis that when two sounds define a minimal pair in a language, then the two sounds are **phonemes** in that language. Thus *t* and *d* are both phonemes of English, and we affirm that English "has both *t* and *d*". We would equivalently say that the difference between [t] and [d] is **contrastive** or **distinctive** in English, and that [t] and [d] **contrast** in English.

The choice of a voiceless aspirated stop such as [t^h] versus a voiceless unaspirated stop such as [t], on the other hand, never defines the sole basis for differentiating words in English – there are no minimals pair establishing that [t^h] is a phoneme that contrasts with [d]. The occurrence of [t] versus [t^h] (also [k] versus [k^h], and [p] versus [p^h]) follows a rule that aspirated stops are exclusively used in one phonological context, and unaspirated stops are used in all other contexts. Thus in English, [t] and [t^h] are predictable variants of a single abstract segment, a **phoneme**, which we represent as /t/. Purely predictable variants are termed **allophones** – the sounds comprising the allophones of a phoneme are in **complementary distribution** because the context where one variant appears is the complement of the context where the other sound appears. In terms of the existing sound (allophones) in the language, [t] and [t^h] both exist in English, but in terms of status as phoneme, only /t/ exists. Whereas no rule can be devised that generates all cases of [t] from /d/ or all cases of [d] from /t/, a rule does allow us to generate all instances of [tʰ] from /t/ (or perhaps generating all instances of [t] from /tʰ/, we discuss this below). It is then possible that at a deeper level of analysis, [t] and [tʰ] are the same thing (one phoneme phoneme), even though later in the phonology they split into two different things (the allophones [t] and [tʰ]).

3.1.1 Aspiration

Now we consider how to predict aspiration in English. In the words of (2), the phonemes /p, t, k/ are aspirated whereas they are not aspirated in words of (3).[1]

(2) *Aspirated stops*

pool	[**pʰ**uwl]	tooth	[**tʰ**uwθ]	coop	[**kʰ**uwp]
pit	[**pʰ**ɪt]	tin	[**tʰ**ɪn]	kill	[**kʰ**ɪl]
apply	[ə**pʰ**laj]	atomic	[ə**tʰ**amɪk]	account	[ə**kʰ**æwnt]
prawn	[**pʰ**ɹan]	truth	[**tʰ**ɹuwθ]	crab	[**kʰ**ɹæb]
pueblo	[**pʰ**wɛblow]	twine	[**tʰ**wajn]	quill	[**kʰ**wɪl]
play	[**pʰ**lej]			clay	[**kʰ**lej]
puce	[**pʰ**juws]			cube	[**kʰ**juwb]

(3) *Unaspirated stops*

spool	[s**p**uwl]	stool	[s**t**uwl]	school	[s**k**uwl]
spit	[s**p**ɪt]	stick	[s**t**ɪk]	skid	[s**k**ɪd]
sap	[sæ**p**]	sat	[sæ**t**]	sack	[sæ**k**]
spray	[s**p**ɹej]	stray	[s**t**ɹej]	screw	[s**k**ɹuw]
split	[s**p**lɪt]			sclerosis	[s**k**ləɹowsɪs]
spew	[s**p**juw]			skew	[s**k**juw]

The selection of an aspirated versus an unaspirated voiceless stop is determined by the phonetic context in which the stop appears. Aspirated stops appear at the beginning of a word, whereas unaspirated stops appear after [s]; aspirated stops appear before a vowel or a sonorant consonant, whereas unaspirated stops appear at the end of a word. Aspirated sound appear between vowels, at least in the examples above (see further examples below). This collection of contexts can be expressed succinctly by referring to the position of the consonant in the syllable: aspirated stops appear at the beginning of the syllable and unaspirated stops appear elsewhere.

[1] The English transcriptions below are not maximally narrow, for example rounding of [ɹ] is omitted. Also, there are competing phonological analyses of English vowels where “ay” in “say” could be transcribed as [ej] as I have done, or [ɛɪ, ɛi, e, eː] and so on. These are simple alternative conventions and not contradictory claims about systematic phonetic output. On the other hand, the choice [æw ~ ɑw] is a real dialect difference.

We assume that the voiceless stops are basically unaspirated in English, and explain where aspirated segments are created by having a rule that assigns aspiration to voiceless stops, when the stop is at the beginning of the syllable. The rule can be stated as "voiceless stops become aspirated at the beginning of a syllable." We don't need a second special rule to derive unaspirated stops in other environments, because that result follows directly from our assumption that the basic or **underlying** form of the voiceless stops in English is unaspirated, and they will therefore be pronounced as such unless they are specifically changed by a rule. We investigate the idea of underlying representations in greater detail in Chapter 5.

The prediction of aspiration in English is a bit more complicated than implied in the above examples. Notice that in the following words, [p], [t] and [k] in the middle of the word are not aspirated, even though the consonant is between vowels or syllabic sonorants – between syllable peaks – and therefore is presumably at the beginning of a syllable.

(4)	ˈhæ**p**ij	happy	ˈkʰæm**p**ɪŋ	camping	ˈhɛl**p**ɪŋ	helping
	ˈlʌ**k**ij	lucky	ˈsʌ**k**ɹ̩	sucker	ˈsal**t**ij	salty

Compare these words with seemingly analogous words where there is aspiration on the stop between vowels, such as [əˈ**tʰ**æk] *attack*, [əˈ**kʰ**juwmjəˌlejt] *accumulate*, [ˈlejˌ**tʰ**ɛks] *latex*, [əˈ**pʰ**ɛndɪks] *appendix*. The important difference in these words is the location of stress. In all of the words in (4), where a voiceless consonant is not aspirated in syllable-initial position, the consonant is followed by an unstressed vowel. In other words, these data force us to refine our statement of the rule for assignment of aspiration, to be "voiceless stops become aspirated at the beginning of a stressed syllable". The next chapter introduces the details for formalizing rules, but for the present we can express that rule as follows.

(5) voiceless stop → aspirated / [ˈ$_\sigma$ __

This statement introduces the standard method of writing rules, which will be used in the book. Rules generally take the form "A→B/C_D," where A, C, D are variables that stand for segments like [l] or [d] or phonetic classes such as "voiceless stop", and B describes the nature of the change, some phonetic parameter such as "voiceless" or "nasal". The conditioning context might involve only a preceding element, in which case "D" would be missing; it might involve only a following element in which case "C" would be missing, or the applicability of the rule might depend on both what precedes and what follows. The things triggering the rule might be one segment, or it might be a specified sequence. The arrow means "becomes," and the slash means "in the environment" where the context is what follows the slash. The notation "[ˈ$_\sigma$" means "beginning of a stressed syllable" (σ stands for "syllable", ˈ marks "stress), thus "voiceless stops become aspirated when then are preceded by the beginning of a stressed syllable". The final chapter of the book introduces syllables in more detail.

Although we see that it is *possible* to predict when voiceless stops are aspirated, we have not given any evidence that aspiration *should* be supplied by a rule rather than being part of the lexical entry. This is a difficult and controversial question to answer, but we will now consider some evidence that aspiration *should* be provided by rule.

Alternations involving aspiration. The dependence of aspiration on the location of stress leads to discovering further evidence for an aspiration rule. Certain word-formation processes in English change the location of stress, for example in ‘atom’ the stress is on the first syllable of the root and in the related adjective ‘atomic’ the stress is on the second syllable. The pairs of words in (6) further illustrate the property of stress shifting, where the verbs on the left have stress on the second syllable of the root but the nouns derived from these verbs on the right have no stress on the second syllable.

(6)	[əˈ**pʰ**laj]	apply	[ˌæ**p**ləˈkʰejʃn̩]	application
	[səˈ**pʰ**owz]	suppose	[ˌsʌ**p**əˈzɪʃn̩]	supposition
	[əˈ**kʰ**wajɹ]	acquire	[ˌæ**k**wəˈzɪʃn̩]	acquisition

As predicted by our rule for aspiration, the phonetic presence or absence of aspiration on the medial stop of the root may alternate within a given root, according to where the stress appears in the root.

Another set of examples involves the word-formation process adding *-ee* to a verb, to form a noun referring to the direct object of the action. That suffix must be stressed, unlike the subject-nominalization suffix *-er*.

(7)	*Verb*	*Subject noun*	*Object noun*	
	[ˈgɹæn**t**]	[ˈgɹæn**t**ɹ̩]	[ˌgɹænˈ**tʰ**i]	grant
	[ˈʃɪf**t**]	[ˈʃɪf**t**ɹ̩]	[ˌʃɪfˈ**tʰ**i]	shift
	[ˈhɛl**p**]	[ˈhɛl**p**ɹ̩]	[ˌhɛlˈ**pʰ**i]	help
	[ˈtᶴʰow**k**]	[ˈtᶴʰow**k**ɹ̩]	[ˌtᶴʰowˈ**kʰ**i]	choke
	[ˈstɹaj**k**]	[ˈstɹaj**k**ɹ̩]	[ˌstɹajˈ**kʰ**i]	strike
	[əˈtʰæ**k**]	[əˈtʰæ**k**ɹ̩]	[əˌtʰæˈ**kʰ**i]	attack

Again, as our rule predicts, when the stress shifts to the suffix vowel, the pronunciation of the preceding consonant changes to become aspirated.

Pronunciation of novel utterances. Not only does the existence of this aspiration rule explain why all voiceless stops are aspirated at the beginning of a stressed syllable in English words, it also explains facts of language behavior by English speakers outside the domain of pronouncing ordinary English words. First, when English speakers are faced with a new word which they have never heard before, for example one coming from a foreign language, voiceless consonants will be aspirated or unaspirated according to the general rule for the distribution of aspiration. The pronunciation of unfamiliar foreign place names provides one simple demonstration. The place names Stord (Norway) and Palma (Mozambique) will be pronounced by English speakers as [stɔɹd] and [pʰalmə], as predicted by the aspiration rule. The name Stavanger (Norway) may be pronounced many ways – [stəˈvæŋɹ̩], [ˈstævənd^{3}ɹ̩], [stəˈvænd^{3}ɹ̩], [ˈstævəŋɹ̩] and so on, but consistently throughout this variation, the /t/ will remain unaspirated because of its position in the syllable. In the English pronunciation of Rapallo (Italy), stress could either be in the first syllable in [ˈɹæpəlow], with no aspiration because /p/ is at the beginning of an unstressed syllable, or on the second syllable as in [ɹəˈpʰalow] – again the choice of aspirated versus unaspirated consonant being determined by the rule of aspiration.

Second, when English speakers attempt to learn a language which does not have the same distribution of aspirated and unaspirated consonants as in English, they encounter difficulties in pronunciation that reflect the effect of the rule of aspiration. Hindi has both aspirated and unaspirated voiceless stops at the beginning of syllables, as well as after /s/. Words such as [pʰal] 'fruit' and [stan] 'breast' are not difficult for English speakers to pronounce; accurate pronunciation of [pal] 'want' and [stʰal] 'place' on the other hand are difficult. This is due to the fact that the rule of aspiration from English interferes in the pronunciation of other languages.

Finally, even in native English words, unaspirated stops can show the effect of the aspiration rule in hyper-slow, syllable-by-syllable pronunciation. Notice that in the normal pronunciation of *happy* [ˈhæpij], only the first syllable is stressed and therefore [p] remains unaspirated. However, if this word is pronounced very slowly, drawing out each vowel, then both syllables become stressed, and as predicted the stop *p* is aspirated – [ˈhæ::]…[ˌpʰi::j]. All of these facts are explained by one simple hypothesis, that in English the occurrence of aspiration on stops derives from applying a rule.

3.1.2 Flapping

Another rule governs predictable variants (allophones) of consonants in English. A phonetic characteristic of many North American and Australian dialects of English is "flapping," where /t/ and /d/ become the flap [ɾ] in certain contexts, for example in [ˈwaɾɹ̩] *water*. There are no minimal pairs such as hypothetical [hɪt] and *[hɪɾ], or *[bʌtɹ̩] and [bʌɾɹ̩], whose existence would establish that the flap is a distinct phoneme of English. Moreover, the contexts where the flap appears in English are quite restricted. In our previous examples of nonaspiration in the context ˈvCv in (4) and (6), no examples included [t] as an intervocalic consonant. Now consider the following words:

Vowels and syllabic sonorants often function together in phonology, and we unify them with the term ***syllabic****.*

The theory of distinctive features given in chapter 5 makes it easier to distinguish different notions of vowel and glide.

(8)	a.	ˈwaɾɹ̩	water	ˈwejɾɹ̩	waiter; wader
		ˈæɾm̩	atom; Adam	ˈæɾəˌtʰuwd	attitude
	b.	ˈhɪt	hit	ˈhɪɾɪŋ	hitting
		ˈpʊt	put	ˈpʊɾɪŋ	putting
		ˈsɛt	set	ˈsɛɾɪŋ	setting

In (8a) orthographic <t> is phonetically realized as the flap [ɾ] in the context ˈV_V, that is, when it is followed by a vowel or syllabic sonorant – represented as V – and preceded by a stressed vowel or syllabic sonorant. Maybe we have just uncovered an orthographic defect of English, since we have no letter for a flap (just as no single letter represents /θ/ vs. /ð/) and some important distinctions in pronunciation are lost in spelling. The second set of examples show even more clearly that underlying *t* becomes a flap in this context. We can convince ourselves that the verbs [hɪt], [pʊt] and [sɛt] end in [t], simply by looking at the uninflected form of the verb, or the third-person-singular forms [hɪts], [pʊts] and [sɛts], where the consonant is pronounced as [t]. Then when we consider the gerund, which combines the root with the suffix -*ɪŋ*, we see that /t/ has become the flap [ɾ]. This provides direct evidence that there must be a rule deriving flaps from plain /t/, since the pronunciation of root morphemes may actually change, depending on whether or not the rule for flapping applies (which depends on whether a vowel follows the root).

There is analogous evidence for an underlying /t/ in the word [ˈæɾm̩] *atom*, since, again, the alveolar consonant in this root may either appear as [t^h] or [ɾ], depending on the phonetic context where the segment appears. Flapping only takes place before an unstressed vowel, and thus in /ætm̩/ the consonant /t/ is pronounced as [ɾ]; but in the related form [əˈt^{h}amɪk] where stress has shifted to the second syllable of the root, we can see that the underlying /t/ surfaces phonetically (as an aspirate, following the previously discussed rule of aspiration).

We may state the rule of flapping as follows: “an alveolar stop becomes a flap when it is followed by an unstressed syllabic and is preceded by a vowel or glide”. You will see how vowels and glides are unified in the next chapter: for the moment, we use the term **vocoid** to refer to the phonetic class of vowels and glides. It is again important to note that the notion of “vowel” used in this rule must include syllabic sonorants such as [ɹ̩] for the preceding segment, and [ɹ̩] or [m̩] for the following segment. The rule is formalized in (9).

(9) alveolar stop → flap / vocoid ___ unstressed syllabic

Flapping is not limited to the voiceless alveolar stop /t/: underlying /d/ also becomes [ɾ] in this same context.

(10)	*Base verbs*	*‘One who V-s’*	*‘V-ing’*	
	ˈbɪd	ˈbɪɾɹ̩	ˈbɪɾɪŋ	bid
	ˈhajd	ˈhajɾɹ̩	ˈhajɾɪŋ	hide
	ˈwejd	ˈwejɾɹ̩	ˈwejɾɪŋ	wade

It is important to understand that “allophone” is a relationship between a surface sound and a phoneme, thus [t^h] is an allophone of the phoneme /t/ and [k^h] is an allophone of the phoneme /k/. [t] is another allophone of /t/; furthermore, [ɾ] is an allophone of /t/ – and, as we see in (10), [ɾ] can be an allophone of /d/. We can then say that an allophone is a segment in a language which is always the result of applying a phonological rule to some phoneme, and which therefore does not exist in underlying representations. But this later reasoning – it can be predicted *therefore* cannot be underlyingly present – is not particularly solid, and leads to unresolved confusion about the significance of allophones. Is it essential that these sounds are definitely missing from underlying forms, or is it that their occurrence can be predicted? This issue remains unresolved to this day.

3.1.3 Glottal stop

There is one context where flapping of /t/ does not occur when preceded by a vowel and followed by an unstressed syllabic segment (vowel or syllabic sonorant), which is when /t/ is followed by a syllabic [n̩]. Consider, first, examples such as [ˈbʌʔn̩] *button* and [ˈkaʔn̩] *cotton*. Instead of the flap that we expect, based on our understanding of the context where flapping takes place, we find glottal stop before syllabic [n̩]. Consider the following pairs of words:

(11)	[rat]	rot	[ˈraʔn̩]	rotten
	[hajt]	height	[ˈhajʔn̩]	heighten
	[lajt]	light	[ˈlajʔn̩]	lighten
	[fæt]	fat	[ˈfæʔn̩]	fatten

The bare roots on the left show the underlying /t/ which has not changed to glottal stop, and on the right, we observe that the addition of the suffix /n/ conditions the change of /t/ to [ʔ] in the context ˈV_n, i.e. when *t* is preceded by a stressed vowel and followed by an alveolar nasal. Words like [ˈærm̩] *atom* show that the glottal stop rule does not apply before all nasals, just alveolar nasals.

Finally, notice that in casual speech, the gerundive suffix *-ɪŋ* may be pronounced as [n̩]. When the verb root ends in /t/, that /t/ becomes [ʔ] just in case the suffix becomes [n̩], and thus provides the crucial context required for the glottal stop creation rule.

> *Some speakers have* [ʔ] *only before syllabic* [n̩]*, so their rule is different. Not all American dialects have this rule – it is lacking in certain Southern US dialects, and instead the flapping rule applies. Some British dialects have a rule which applies in a rather different context, e.g.* [lɛʔə] letter.

(12)	*Base verb*	*Careful speech*	*Casual speech*
	hɪs	hɪsɪŋ	hɪsn̩
	ɹat	ɹaɾɪŋ	ɹaʔn̩
	flowt	flowɾɪŋ	flowʔn̩

In the examples considered so far, the environment for appearance of glottal stop has been a following syllabic [n̩]. Is it crucial that the triggering nasal segment be specifically a syllabic nasal? We also find glottal stop before nonsyllabic nasals in words such as *Whitney* [ʍɪʔnij] and *fatness* [fæʔnəs], which shows that the *t*-glottalization rule does not care about the syllabicity of the following nasal. The presence of glottal stop in these examples can be explained by the existence of a rule which turns /t/ into glottal stop before [n] or [n̩].

(13) alveolar stop → glottal stop / __ alveolar nasal

Notice that this rule applies before a set of segments, but not a random set: it applies before alveolar nasals, without mention of syllabicity. As we will repeatedly see, the conditioning context of phonological rules is stated in terms of phonetic properties.

3.2 Allophony in other languages

Allophonic rules of pronunciation are found in most human languages, if not indeed all languages. What constitutes a subtle contextual variation in one language may constitute a wholesale radical difference in phonemes in another. The difference between unaspirated and aspirated voiceless stops in English is a completely predictable, allophonic one which speakers are not aware of, but in Hindi the contrast between aspirated and unaspirated voiceless consonants forms the basis of phonemic contrasts, e.g. [pal] 'want', [p^{h}al] 'fruit.' Unlike the situation in English, aspiration in Hindi is an important, distinctive property of stops which cannot be supplied by a rule.

***l* and *d* in Tswana.** The consonants [l] and [d] are clearly separate phonemes in English, given words such as *lie* and *die* or *mill* and *mid*. However, in Tswana (Botswana), there is no contrast between [l] and [d]. Phonetic [l] and [d] are contextually determined variants of a single phoneme: surface [l] appears before nonhigh vowels, and [d] appears before high vowels (neither consonant may come at the end of a word or before another consonant).

(14)	**l**efifi	'darkness'	**l**o**l**eme	'tongue'
	se**l**ɛpɛ	'axe'	mo**l**ɔmo	'mouth'
	xoba**l**a	'to read'	mma**d**i	'reader'
	lerumɔ	'spear'	xoŋa**l**a	'to marry'
	loxa**d**ima	'lightning flash'	**d**id^{ʒ}ɔ	'food'
	dumɛ**l**a	'greetings'	fee**d**i	'sweeper'
	lokwa**l**ɔ	'letter'	k^{h}u**d**u	'tortoise'
	mosa**d**i	'woman'	po**d**i	'goat'
	ba**d**isa	'the herd'	hu**d**i	'wild duck'

Tswana has a rule which can be stated as "/l/ becomes [d] before high vowels."

(15) l → d/ _ high vowel

An equally accurate and general statement of the distribution or [l] and [d] would be "/d/ becomes [l] before nonhigh vowels."

(16) d → l/ _ nonhigh vowel

There is no evidence to show whether the underlying segment is basically /l/ or /d/ in Setswana, so we would be equally justified in assuming either rule (15) or rule (16). Sometimes, a language does not provide enough evidence to allow us to decide which of two (or more) analyses in correct.

Tohono O'odham affricates. In the language Tohono O'odham (formerly known as Papago: Arizona and Mexico), there is no contrast between [d] and [d^{ʒ}], or between [t] and [t^{ʃ}]. The task is to inspect the examples in (17) and discover what factor governs the choice between plain alveolar [d, t] versus the alveopalatal affricates [d^{ʒ}, t^{ʃ}]. In these examples, word-final sonorants are devoiced by a regular rule which we disregard, explaining the devoiced *m* in examples like [waht^{ʃ}um̥]

(17)	**d^{ʒ}**ihsk	'aunt'	**d**ɔʔaʔk	'mountain'
	t^{ʃ}u:li̥	'corner'	**t^{ʃ}**ɯwaʔgi̥	'clouds'
	wah**t^{ʃ}**um̥	'drown'	**t**ah**t**	'foot'
	d^{ʒ}ɯwɯhkɔh	'cut hair'	ʔahi**d**aʔk	'year'
	tɔnɔm̥	'be thirsty'	hɯh**t**ahpsp**t^{ʃ}**u̥	'make it 5'
	hɯ**d^{ʒ}**ɯli̥	'self'	**t^{ʃ}**ihkpan̥	'work'
	s**t**ah**t**ɔnɔm:ah	'thirsty times'	ʔi:**d**ḁ	'this'
	mɯɖɯ**d**am̥	'runner'	**t**ɔhn**t**ɔ̥	'degenerate'
	tɔdsi**d**	'frighten'	**t^{ʃ}**ɯpɔsi**d**	'brand'
	gah**t**wi̥	'to shoot'	**t^{ʃ}**ɯh**t^{ʃ}**i̥	'name'
	gɯʔɯ**dt**ḁ	'get big'	**d^{ʒ}**umali̥	'low'
	tobi**d**k	'White Clay'	waʔ**d^{ʒ}**iwih	'swim'
	spa**d**mahkam̥	'lazy one'	**d^{ʒ}**u:ʔw̥	'rabbits'

We do not know, at the outset, what factor conditions the choice of [t, d] versus [t^{ʃ}, d^{ʒ}] (indeed, in the world of actual analysis we do not know in advance that there *is* any such relationship; but to make your task easier, we will at least start with the knowledge that there is a predictable relationship, and concentrate on discovering the rule governing that choice). To begin solving the problem, we explore two possibilities: the triggering context may be the segment which immediately precedes the consonant, or it may be the segment which immediately follows it.

Let us start with the hypothesis that it is the immediately preceding segment which determines how the consonant is pronounced. In order to organize the data so as to reveal what rule might be at work, we can simply list the preceding environments where stops versus affricates appear, so *h_* means "when [h] precedes" – here, the symbol '#' represents the beginning or end of a word. Looking at the examples in (17), and taking note of what comes immediately before any [t, d] versus [t^{ʃ}, d^{ʒ}], we arrive at the following list of contexts:

(18) [t, d]: #_, h_, ɯ_, i: _, s_, i_, n_, ɔ_
[t^{ʃ}, d^{ʒ}]: #_, h_, ɯ_, ʔ_, p_

Since both types of consonants appear at the beginning of the word, or when preceded by [h] or [ɯ], it is obvious that the preceding context cannot be the crucial determining factor. We therefore reject the idea that the preceding element determines how the phoneme is pronounced.

Focusing next on what follows the consonant, the list of contexts correlated with plain stops versus affricates is much simpler.

(19) [t, d]: _ ɔ, _a, _ḁ, _#, _s, _t, _k, _ m, _w

[t^{ʃ}, d^{ʒ}]: _i, _i̥, _u, _u̥, _ɯ

Only the vowels [i, u, ɯ] (and their devoiced counterparts) follow [t^{ʃ}] and [d^{ʒ}], and the vowels [a, ɔ] follow [t] and [d]. Moreover, when no vowel follows, i.e. at the end of the word or before another consonant, the plain alveolar appears (*taht, tɔdsid*). The vowels [i, u, ɯ] have in common the property that they are high vowels, which allows us to state the context for this rule very simply: /t/ and /d/ become alveopalatal affricates before high vowels, i.e.

(20) alveolar stop → alveopalatal affricate / _high vowel

The retroflex consonant [ɖ] does not undergo this process, as seen in [mɯɖɯdam̥].

This account of the distribution of alveolars versus alveopalatals assumes that underlyingly the consonants are alveolars, and that just in case a high vowel follows, the consonant becomes an alveopalatal affricate. It is important to also consider the competing hypothesis that underlyingly the consonants are alveopalatals and that they become alveolars in a context which is complementary to that stated in rule (20). The problem with that hypothesis is that there is no natural statement of that complementary context, which includes nonhigh vowels, consonants, and the end of the word.

(21) $$\text{alveopalatal affricate} \rightarrow \text{alveolar stop} \, / \, \_ \left\{ \begin{matrix} \text{nonhigh V} \\ \text{C} \\ \# \end{matrix} \right\}$$

The brace notation is a device used to force a disjunction of unrelated contexts into a single rule, so this rule states that alveopalatal affricates become alveolar stops when they are followed either by a nonhigh vowel, a consonant, or are at the end of the word, i.e. there is no coherent generalization. Since the alternative hypothesis that the consonants in question are underlyingly alveopalatals leads to a much more complicated and less enlightening statement of the distribution of the consonants, we reject the alternative hypothesis and assume that the consonants are underlyingly alveolar.

Obstruent voicing in Kipsigis. In the Kipsigis language of Kenya, there is no phonemic contrast between voiced and voiceless obstruents as there is in English. No words are distinguished by the selection of voiced versus voiceless consonants: nevertheless, phonetic voiced obstruents do exist in the language.

(22)	**k**uur	‘call!’	**ke-g**uur	‘to call’
	ŋo**k-t**a	‘dog’	ŋo**g-**ii**k**	‘dogs’
	kɛ-tɛp	‘request’	i**-teb-**e	‘you are requesting’
	ker	‘look at!’	**ke-g**er	‘to look at’
	put	‘break up!’	**ke-but**	‘to break up’

poor	'thresh maize!'	**k**e-**b**oor	'to thresh maize'
ŋelje**p**-**t**a	'tongue'	ŋelje**b**-we**k**	'tongues'
kisi**pt**ʃi	'to follow for'	iŋ**g**urwe**t**	'pig'
ki**pk**irui	(name)	**k**e-**b**aa**kp**aa**k**	'to strip repeatedly'
pʊn**b**ʊn	'soft'	**t**ilɑ**k**se	'it is cuttable'
kir**g**i**t**	'bull'	**k**a**g**jam	'we ate'
taa**pt**ɛɛ**t**	'flower type'	**k**e**b**ri**t**ɑmɛɛ**t**	'to fall asleep'
kɪ**b**laŋa**t**	(name)	**p**ee**t**ʃiŋ**g**e	'they are going for 'themselves'

In these examples, we can see that the labial and velar consonants ("peripheral", a matter which we look into in the next chapter) become voiced when they are both preceded and followed by vowels, liquids, nasals and glides: these are all sounds which are voiced.

(23) voiceless peripheral consonant → voiced / voiced _ voiced

In stating the context, we do not need to say "voiced vowel, liquid, nasal or glide," since, by saying "voiced" alone, we refer to the entire class of voiced segments. It is only when we need to specifically restrict the rule so that it applies just between voiced consonants, for example, that we would need to further specify the conditioning class of segments.

While you have been told that there is no contrast between [k] and [g] or between [p] and [b] in this language, children learning the language do not use explicit instructions, so an important question arises: how can you arrive at the conclusion that the choice [k, p] versus [g, b] is predictable? Two facts lead to this conclusion. First, analyzing the distribution of consonants in the language would lead to discovering the regularities that no word begins or ends in [b, g] and no word has [b, g] in combination with another consonant, except in combination with the voiced sonorants. We would also discover that [p, k] do not appear between vowels, or more generally between voiced segments. If there were no rule governing the distribution of consonants in this language, then the distribution is presumed to be random, which would mean that we should find examples of [b, g] at the beginning or end of words, or [p, k] between vowels.

Another very important clue in understanding the system is the fact that the pronunciation of morphemes will actually change according to the context that they appear in. Notice, for example, that the imperative form [kuur] 'call!' has a voiceless stop, but the same root is pronounced as [guur] in the infinitive [ke-guur] 'to call.' When learning words in the language, the child must resolve the changes in pronunciation of word-parts in order to know exactly what must be learned. Sometimes the root 'call' is [kuur], sometimes [guur] – when are you supposed to use the pronunciation [guur]? Similarly, in trying to figure out the root for the word 'dog,' a child will observe that in the singular the root portion of the word is pronounced [ŋok], and in the plural it is pronounced [ŋog]. From observing that there is an alternation between [k] and [g], or [p] and [b], it is a relatively simple matter to arrive at the hypothesis that there is a systematic relation between these sounds, which leads to an investigation of when [k, p] appear, versus [g, b].

Implosive and plain voiced stops in Matuumbi. The distinction between implosive and plain voiced consonants in Matuumbi (Tanzania) can be predicted by a rule.

(24)

ɓɛɓɛɛlu	'male goat'	ɠundumuka	'be scared'
ɓutuka	'flow'	ɠaala	'storage in roof'
kɔɓɔkwa	'unfold'	ɓwʊʊmɪ	'life'
kɔɔndwa	'dig clay'	ŋgaambalɛ	'fish sp.'
ɓalaka	'luck'	ɠʊlʊja	'drive fast'
lisɛɛŋgɛlɛ	'dowry'	ɓila	'without'
ɠɔlɔja	'straighten'	ɠuna	'murmur'
kiɓʊla	'towards Mecca'	kitʊʊmbɪ	'hill'
kjaaŋgi	'sand'	ɓɔmwaana	'destroy'
likʊʊŋgwa	'storage structure'	ɓʊʊka	'leave'
ɠɔɔmba	'shoot a gun'	ɠʊlʊka	'fly'
ɓalaaŋga	'count'	aliɓika	'be out of order'

Upon consideration of consonant distribution in these data, you will see that implosives appear in word-initial position and after vowels, whereas plain voiced consonants appear exclusively after nasals.

There is further clinching evidence that this generalization is valid. In this language, the first-person-singular form of the verb has a nasal consonant prefix (there is also a change in the final vowel, where you get -*a* in the infinitive and -*ɛ* in the "should" form, the second column below).

(25)

to V	*I should V*	
ɠʊlʊka	ŋgʊlʊkɛ	'fly'
ɠɔɔmba	ŋgɔɔmbɛ	'shoot a gun'
ɠɔlɔja	ŋgɔlɔjɛ	'straighten'
ɠuna	ŋgunɛ	'murmur'
ɓalaaŋga	mbalaaŋgɛ	'count'
ɓutuka	mbutukɛ	'flow'
ɓʊʊka	mbʊʊkɛ	'leave'
ɗuumu	nduumu	'continue'

Thus the pronunciation of the root for the word for 'fly' alternates between [ɠʊlʊk] and [gʊlʊk], depending on whether a nasal precedes.

Having determined that implosives and plain voiced stops are allophonically related in the grammar of Matuumbi, it remains to be decided whether the language has basically only plain voiced consonants, with implosives appearing in a special environment; or whether Matuumbi voiced stops are basically implosive, and plain voiced consonants appear only in a complementary environment. The matter boils down to the following question: is it easier to state the context where implosives appear, or is it easier to state the context where plain voiced consonants appear? We generally assume that the variant with the most easily stated distributional context is the variant derived by applying a rule. However, as we saw with the case of [l] and [d] in Tswana, a language may not provide empirical evidence which is the correct solution.

Now let us compare the two possible rules for Matuumbi: "implosives appear word initially and after a vowel":

(26) $$\text{C} \rightarrow \text{implosive} / \begin{Bmatrix} V \\ \# \end{Bmatrix} \; -$$

versus "plain consonants appear after a nasal":

(27) C → nonimplosive / nasal _

It is simpler to state the context where plain consonants appear, since their distribution requires a single context – after a nasal – whereas describing the process as replacement of plain consonants by implosives would require a more complex disjunction "either after a vowel, or in word-initial position." A concise description of contexts results if we assume that voiced consonants in Matuumbi are basically implosive, and that the nonimplosive variants which appear after nasals are derived by a simple rule: implosives become plain voiced consonants after nasals.

It is worth noting that another statement of the implosive-to-plain process is possible, since sequences of consonants are quite restricted in Matuumbi. Only a nasal may precede another "true" consonant, i.e. a consonant other than a glide. A different statement of the rule, one which is just as factually valid as (27), is that plain voiced consonants appear only after C (a consonant). No fact in the language tells us whether the rule is based on "nasal" versus "consonant". Phonological theory does not always give a single solution for any given data set, so we must accept that there are at least two ways of describing this pattern. One of the goals of the theory, towards which considerable research energy is being expended, is developing a principled basis for making a unique and correct choice in such cases where the data themselves cannot show which solution is right. In developing rules for datasets presented here, you will frequently be faced with two ways to formalize a rule, both equally correct and simple.

Velar and uvular stops in Kenyang. In Kenyang (Cameroon), there is no contrast between the velar consonant *k* and uvular *q*.

(28)	enɔ**q**	'tree'	eno**q**	'drum'
	e**k**et	'house'	ntʃi**k**u	'I am buying'
	ne**k**	'rope'	ejwɑrek	'sweet potato'
	ŋgɑ**q**	'knife'	ekɑ**q**	'leg'
	mə**k**	'dirt'	nɑ**q**	'brother in law'
	nde**k**	'European'	pəbri**k**	'work project'

betə**k**	'job'	bepə**k**	'to capsize'
ti**k**u	(name)	**k**u	'buy!'
ɑju**k**	(name)	esi**k**ɔŋ	'pipe'
kebwep	'stammering'	ŋ**kɔq**	'chicken'
ŋ**k**ɑp	'money'	**k**ɔ	'walk!'

What determines the selection of *k* versus *q* is the nature of the vowel which precedes the consonant. The uvular consonant *q* is always preceded by one of the back nonhigh vowels *o,* ɔ or ɑ, whereas velar *k* appears anywhere else.

(29) voiceless velar → uvular / back nonhigh vowel _

This relation between vowels and consonants is phonetically natural. The vowels triggering the change have a common place of articulation: they are produced at the lower back region of the pharynx, where *q* (as opposed to *k*) is articulated.

An alternative analysis is that the underlying segment is a uvular, and velar consonants are derived by rule. But under that assumption, the rule which derives velars is very complex. Velars would be preceded by front or central vowels, by high back vowels, by a consonant (ŋ), or by a word boundary. We would then end up with a disjunction of contexts in our statement of the rule.

(30) $$\mathrm{q} \rightarrow \mathrm{k} \,/ \left\{\begin{array}{c}\text{front V}\\ \text{central V}\\ \text{high back V}\\ \mathrm{C}\\ \#\end{array}\right\} -$$

The considerably more complex rule deriving velars from uvulars leads us to reject the hypothesis that these segments are underlyingly uvular. Again, we are faced with one way of capturing the generalization exploiting phonetically defined classes, and an alternative that involves a disjunctive list, where there is nothing that unifies the contexts: we select the alternative which allows a rule to be stated that refers to a simple, phonetically defineable context. This decision reflects an important discovery regarding the nature of phonogical rules which will be discussed in greater detail in chapter 3, namely that phonological rules operate in terms of phonetic classes of segments.

Arabela nasalization. Nasalization of vowels and glides is predictable in Arabela (Peru).

(31)	nẽẽkjææʔ	'lying on back'	mõnũʔ	'kill'
	tukuruʔ	'palm leaf'	ʃijokwaʔ	'grease'
	nj̃æ̃æ̃riʔ	'he laid it down'	suroʔ	'monkey'
	nĩĩkjææʔ	'is pouring out'	suwakaʔ	'fish'
	posunãh̃ãʔ	'short person'	kuwɔxoʔ	'hole'
	nõõnũʔ	'be pained'	h̃ẽẽgiʔ	'termites'

tæweʔ	‘foreigner’	h̃j̃ũũʃʃænõʔ	‘where I fished’
nĩnj̃ũʔ	‘to come’	mj̃æ̃nũʔ	‘swallow’
nũw̃ãʔ	‘partridge’	h̃ũw̃ãʔ	‘a yellow bird’

Scanning the data in (31), we see nothing about the following phonetic context that explains occurrence of nasalization: both oral and nasal vowels precede glottal stop ([tæw**e**ʔ] ‘foreigner’ versus [nõõn**ũ**ʔ] ‘be pained’), [k] ([nĩ**ĩ**kjææʔ] ‘is pouring out’ versus [ʃij**o**kwaʔ] ‘grease’) or [n] ([mj̃**æ̃**nũʔ] ‘swallow’ versus [pos**u**nãh̃ãʔ] ‘short person’). A regularity does emerge once we look at what precedes oral versus nasal vowels: when a vowel or glide is preceded by a nasal segment – be it a nasal consonant (including [h̃] which is always nasal in this language), vowel, or glide – then a vowel or glide becomes nasalized. The rule for nasalization can be stated as “a vowel or glide becomes nasalized after any nasal sound.”

(32) vocoid → nasal / nasal_

The naturalness of this rule should be obvious – the essential property that defines the conditioning class of segment, nasality, is the very property that is added to the vowel: such a process, where a segment becomes more like some neighboring segment, is known as an **assimilation**. Predictable nasalization of vowels almost always derives from a nasal consonant somewhere near the vowel.

Sundanese: a problem for the student to solve. Bearing this suggestion in mind, where do nasalized vowels appear in Sundanese (Indonesia), given these data?

(33)	abot	‘heavy’	agɨŋ	‘big’
	amĩs	‘sweet’	anõm	‘young’
	handap	‘light’	luhur	‘high’
	awon	‘bad’	basɨr	‘wet’
	konẽŋ	‘yellow’	bɨrɨm	‘red’
	eŋgal	‘new’	gədde	‘big’
	mãhĩr	‘skillful’	mĩrɨ	‘uncertain’
	mõhẽhẽd	‘poor’	bumĩ	‘house’
	mə̃rri	‘duck’	mãhãsiswa	‘student’
	mãũŋ	‘tiger’	mĩãsih	‘true love’
	mĩliar	‘billion’	mĩɲãk	‘oil’
	mũãra	‘confluence’	pamõhãlan	‘impossible’
	mãẽn	‘play’	mãõt	‘die’
	nãʔãs	‘get worse’	mĩʔĩs	‘leak’
	mãʔãp	‘excuse me’	mãhĩ	‘enough’
	nẽwak	‘catch’	tiʔis	‘cold’

Since the focus at the moment is on finding phonological regularities, and not on manipulating a particular formalism (which we have not yet presented completely), you should concentrate on expressing the generalization in clear English.

We can also predict the occurrence of long (double) consonants in Sundanese, using the above data supplemented with the data in (34).

(34)	abuabu	'grey'	bəddil	'gun'
	gəttih	'blood'	akar	'root'
	səddih	'sad'	dʒənnə̃ŋŋãn	'name'
	bərrəkkah	'useful'	bagoŋ	'wild pig'
	babi	'pig'	kinã	'quinine'
	təbbih	'far'	bapa	'father'
	bɨbɨr	'belt'	ŋə̃ppel	'sweep'
	bənnə̃r	'correct'	sɨkɨt	'sharp'
	panãs	'hot'	mə̃ddəm	'dark'
	hukum	'law'	sərrat	'letter'
	kamẽdʒa	'shirt'	patʃul	'shovel'
	bənnãŋ	'thread'	dada	'torso'
	pəttis	'fish sauce'	dʒaŋkuŋ	'tall'
	asəm	'tamarind'	wawəs	'tooth'

What rule determines the length of consonants in this language?

Vowel length in Mohawk. The context for predicting some variant of a phoneme may include more than one factor. There is no contrast between long and short vowels in Mohawk (North America): what is the generalization regarding where long versus short vowels appear?

(35)	ranaˈhe:zʌ̃s	'he trusts her'	raˈge:das	'he scrapes'
	ˈi:geks	'I eat it'	oˈda:we	'flea'
	gaˈda:dis	'I talk'	ʌ̃khˈni:nũʔ	'I will buy it'
	ˈsdũ:ha	'a little bit'	apˈlam	'Abram'
	ʌ̃ˈga:radeʔ	'I lay myself down'	ˈdʌ̃:gehgweʔ	'I'll lift it'
	raˈjʌ̃thos	'he plants'	ˈjegreks	'I push it'
	ˈwisk	'five'	roˈjoʔdeʔ	'he works'
	awerˈjahsa	'heart'	ˈjagwaks	'they and I eat it'
	ˈisgʌ̃s	'you (sg) see her'	gatˈgahthos	'I look at it'
	joˈkekhaʔ	'it's burning'	ʌ̃ˈgidjeʔ	'I will fly around'

One property which holds true of all long vowels is that they appear in stressed syllables: there are no unstressed long vowels. However, it would be incorrect to state the rule as lengthening all stressed vowels, because there are stressed short vowels as in [ˈwisk]. We must find a further property which distinguishes those stressed vowels which become lengthened from those which do not. Looking only at stressed vowels, we can see that short vowels appear before two consonants and long vowels appear before a consonant-plus-vowel sequence. It is the combination of two factors, being stressed and being before the sequence CV, which conditions the appearance of long vowels: stressed vowels are lengthened if they precede CV, and vowels remain short otherwise. We hypothesize the following rule:

(36) stressed V → long /_CV

Since there is no lexical contrast between long and short vowels in Mohawk, we assume that all vowels have the same underlying length: all long and shortened in one context, or all short and lengthened in the complementary context. One hypothesis about underlying forms in a given language results in simpler grammars which capture generalizations about the language more directly than do other hypotheses about underlying forms. If all vowels in Mohawk are underlyingly long, you must devise a rule to derive short vowels. No single generalization covers all contexts where supposed vowel shortening takes place, so your analysis would require two rules, one to shorten unstressed vowels, and another to shorten vowels followed by two consonants. In comparison, the single rule that stressed vowels lengthen before CV accounts for vowel length under the hypothesis that vowels in Mohawk are underlyingly short. No other rule is needed: short vowels appear everywhere that they are not lengthened.

Aspiration in Ossetic. Aspiration can be predicted in Ossetic (Caucasus).

(37)	t^{h}əχ	'strength'	k^{h}ɔttag	'linen'
	χɔstɔg	'near'	ɔftən	'be added'
	fadat^{h}	'possibility'	k^{h}astən	'I looked'
	t^{sh}ɔst	'eye'	k^{h}ark^{h}	'hen'
	akkag	'adequate'	dəkkag	'second'
	t^{sh}əppar	'four'	t^{sh}ət^{h}	'honor'
	t^{sh}əχt	'cheese'	k^{h}ɔm	'where'
	fɔste	'behind'	k^{h}om	'mouth'
	p^{h}irən	'comb wool'	zaχta	'he told'
	χɔskard	'scissors'	χɔston	'military'
	p^{h}ɔrrɔst	'fluttering'		

Since aspirated and plain consonants appear at the end of the word ([t^{sh}ɔst] 'eye,' [t^{sh}ət^{h}] 'honor'), the following context alone cannot govern aspiration. Focusing on what precedes the consonant, aspirates appear word initially, or when preceded by a vowel or [r] (i.e. a sonorant) at the end of the word; unaspirated consonants appear when before or after an obstruent. It is possible to start with unaspirated consonants (as we did for English) and predict aspiration, but a simpler description emerges if we start from the assumption that voiceless stops are basically aspirated in Ossetic, and deaspirate a consonant next to an obstruent. The relative simplicity of the resulting analysis should guide your decisions about underlying forms, and not a priori decisions about the phonetic nature of the underlying segments that your analysis results in.

Optional rules. Some rules of pronunciation are optional, often known as "free variation." In Makonde (Mozambique), the phoneme /ʃ/ can be pronounced as either [s] or [ʃ] by speakers of the language: the same speaker may use [s] one time and [ʃ] another time. The verb 'read' is thus pronounced as *ʃoomja* or as *soomja*, and 'sell' is pronounced as *ʃuluuʃa* or as *suluusa*. We will indicate such variation in pronounciation by giving the examples as "*ʃuluuʃa* ~ *suluusa* ," meaning that the word is pronounceable either as *ʃuluuʃa* or as *suluusa*, as the speaker chooses. Such apparently unconditioned fluctuations in pronunciation are the result of a rule in Makonde which turns /ʃ/ into [s]: this rule is optional. The optional nature of the rule is indicated simply by writing "optional" to the side of the rule.

(38) ʃ → s **optional**

Normally, any rule in the grammar always applies if its phonological conditions are satisfied. An optional rule may either apply or not, so for any optional rule at least two phonetic outcomes are possible: either the rule applies, or it does not apply. Assuming the underlying form /ʃoomja/, the pronunciation [ʃoomja] results if the rule is not applied, and [soomja] results if the rule is applied.

Optional rules may have environmental conditions on them. In Matuumbi, as we have seen in (24), voiced stops are implosive except after a nasal. The voiced velar stop exhibits a further complication, that after a vowel (but not initially) underlying /ɠ/ optionally becomes a fricative [ɣ] (the symbol "~ " indicates "may also be pronounced as").

(39)	ɓaɠana	~	ɓaɣana	'divide'
	ɓiliɠana	~	ɓiliɣana	'wrestle'
	ɓulaɠa	~	ɓulaɣa	'kill'
	ɠalaambuka	~	(*ɣalaambuka)	'change'

Hence the optional realization of /ɠ/ as [ɣ], but only after a vowel, can be explained by the following rule.

(40) ɠ → ɣ / V _ (optional)

The factors determining which variant is selected are individual and sociological, reflecting age, ethnicity, gender, and geography, inter alia. Phonology does not try to explain why people make the choices they do: that lies in the domain of sociolinguistics. We are also only concerned with systematic options. Some speakers of English vary between [æks] and [æsk] as their pronunciation of *ask*. This is a quirk of a particular word: no speaker says *[mæks] for *mask*, or *[fisk] for *fix*.

It would also be mistaken to think that there is one grammar for all speakers of English (or German, or Kimatuumbi) and that dialect variation is expressed via a number of optional rules within a single grammar. From the perspective of grammars as objects describing the linguistic competence of individuals, an optional rule is countenanced only if the speaker can actually pronounce words in multiple ways. In the case of Makonde, some speakers actually pronounce /ʃoomja/ in two different ways.

Are allophonic rules "physical" or "symbolic"? We saw in Ch. 2 that the Logoori velar consonants *k* and *g* are produced with a highly variable degree of constriction, defying strict classification as "stop" versus "fricative". Our conclusion there was that this variation should not be treated as being phonological at all, instead we would look to a physical model of how phonological outputs are physically realized. All that exists in Logoori phonology, in the realm of velar obstruents, is [k] and [g].

Perhaps someone might, through more-extended study of the language, devise a way to organize the apparently continuous range of outputs into a system of allophonic rules, if we increase the set of transcriptional symbols to allow for many sub-types of *k* and *g*. There are also ancilliary transcriptional notations in the IPA, the relative-articulation markers "up tack" [˔] and "down tack" [˕] which indicate "raised / lowered relative to reference value", and someone might develop standards for assigning particular tokens to the categories [g], [g̞], [ɣ̝], [ɣ], [ɣ̞] or [ɰ]. The basic logic of a phonological analysis of sound variation is that phonology produces categories, not continua, therefore if what exists in a language is a two-way choice – a bi-modal distribution of sound properties – the phenomenon should be treated phonologically, but if there is a unimodal distribution of sound properties, i.e. one mean and continuous range of dispersion, the phenomenon should be treated as phonetic.

Since most languages are not subject to rigorous instrumental investigation aimed at establishing the categorial nature of facts of pronunciation, we usually lack the kinds of facts which clarify whether a phenomenon is necessarily in phonology rather than phonetics. Even for a well-studied language like Spanish, there can persist controversy and uncertainty, for example whether the distribution of [b d g] versus [β ð γ] is due to a phonological rule, or a principle of phonetic implementation, as discussed in Hualde (2025).

Summary

Contrastive aspects of pronunciation cannot be predicted by rule, but *allophonic* details can be. Allophonic changes are a type of rule-governed phonological behavior, and phonology is concerned with the study of rules. The practical concern of this chapter is understanding the method for discovering those rules. The linguist looks for regularities in the distribution of one sound versus others, and attempts to reduce multiple surface segments to one basic segment, a *phoneme*, where the related segments derive by applying a rule to the underlying phoneme in some context. Going beyond static distribution of sounds, you should look for cases where the pronunciation of morphemes changes, depending on the presence or absence of prefixes and suffixes.

Assuming that sounds are in complementary distribution, you need to determine which variant is the "basic" underlying one, and which derives by rule. The decision is made by comparing the consequences of alternative hypotheses. Sometimes, selecting underlying /X/ results in a very simple rule for deriving the surface variant [Y] whereas selecting underlying /Y/ results in very complex rules for deriving [X] from /Y/: in such a case, the choice of /X/ over /Y/ is well motivated. Sometimes, no definitive decision can be made.

Exercises

1 Kuria

Provide rules to explain the distribution of the consonants [β, r, γ] and [b, d, g] in the following data. (Note that [r] is a fricative consonant in this language.) Accents mark tone: acute is high tone and "hacek" [ˇ] is rising tone.

aβaánto	'people'	aβamúra	'young men'
amahííndi	'corn cobs'	amakɛ́ɛ́ndɔ	'date fruits'
eβǎ	'forget!'	eeŋgwé	'leopard'
eγǎ	'learn!'	ekeβwɛ́	'fox'
hoorá	'thresh!'	iβiγúrúβe	'small pigs'
iβirúúŋgúuri	'soft porridges'	uγusíri	'huge rope'
βáinu	'you (pl)'	βorjó	'on the right'
it^{ʃ}iiŋgɛ́na	'grinding stones'	it^{ʃ}iiŋgúrúβe	'pig'
γaβǎ	'share!'	it^{ʃ}iiŋgúta	'walls'
βɛrɛká	'carry a child!'	iγitúúmbe	'stool'
γúúká	'ancestor'	remǎ	'weed!'
rɛɛntá	'bring!'	oβoγááká	'male adulthood'
oβotééndééru	'smoothness'	okoγéémbá	'to cause rain'
okoómbára	'to count me'	okoβára	'to count'
okoóndɔ́γa	'to bewitch me'	okorɔ́γa	'to bewitch'
romǎ	'bite!'	teγetá	'be late!'
ukuúmbuurjá	'to ask me'	uruγúta	'wall'

2 Modern Greek

Determine whether the two segments [k] and [k^j] are contrastive or are governed by rule; similarly, determine whether the difference between [x] and [x^j] is contrastive or predictable. If the distribution is rule-governed, what is the rule and what do you assume to be the underlying consonants in these cases?

kano	'do'	kori	'daughter'
xano	'lose'	xori	'dances'
x^{j}ino	'pour'	k^{j}ino	'move'
krima	'shame'	xrima	'money'
xufta	'handful'	kufeta	'bonbons'
kali	'charms'	xali	'plight'
x^{j}eli	'eel'	k^{j}eri	'candle'
x^{j}eri	'hand'	ox^{j}i	'no'

3 Farsi

Describe the distribution of the trills [r], [r̥] and the flap [ɾ].

ærteʃ	‘army’	farsi	‘Persian’
qædri	‘a little bit’	rah	‘road’
rast	‘right’	riʃ	‘beard’
ahar̥	‘starch’	axær̥	‘last’
hærtowr̥	‘however’	ʃir̥	‘lion’
ahaɾi	‘starched’	bæɾadær̥	‘brother’
t^{ʃ}eɾa	‘why?’	daɾid	‘you have’
biɾæng	‘pale’	ʃiɾini	‘pastry’

4 Osage

What rule governs the distribution of [d] versus [ð] in the following data?

ˈdabrĩ	‘three’	ˈaðikhãʒã	‘he lay down’
dat^{ʃ}ˈpe	‘to eat’	ˈt^{ʃ}ʔeðe	‘he killed it’
dakˈʔe	‘to dig’	ˈðeze	‘tongue’
ˈdalĩ	‘good’	ˈðie	‘you’
daʃˈtu	‘to bite’	ˈðiʃki	‘to wash’

5 Amharic

Is there a phonemic contrast between the vowels [ə] and [ɛ] in Amharic? If not, say what rule governs the distribution of these vowels, and what the underlying value of the vowel is.

fərəs	‘horse’	tənəsa	‘stand up!’
jɛlɨd^{ʒ}lɨd^{ʒ}	‘grandchild’	majɛt	‘see’
gənzəb	‘money’	d^{ʒ}ɛgna	‘brave’
nəɲ	‘I am’	məwdəd	‘to like’
mənnəsat	‘get up’	məmkər	‘advise’
ʒɛle	‘unarmed’	jɛlləm	‘no’
mət^{ʃ}	‘when’	məst’ət	‘give’
fəlləgə	‘he wanted’	agəɲɲɛ	‘he found’
təmət^{ʃ}t^{ʃ}ɛ	‘it got comfortable’	mokkərə	‘he tried’
k’aʒʒɛ	‘he talked in his sleep’	ʒɛmmərə	‘he started’
lat^{ʃ}t^{ʃ}’ɛ	‘he shaved’	aʃʃɛ	‘he rubbed’
bəkk’ələ	‘it germinated’	ʃɛməggələ	‘he became old’

6 Gen

Determine the rule which accounts for the distribution of [r] and [l] in the following data.

agble	‘farm’	agoŋglo	‘lizard’
aŋɔli	‘ghost’	akplɔ	‘spear’
sabulɛ	‘onion’	sra	‘strain’
alɔ	‘hand’	atitrwɛ	‘red billed wood dove’
avlɔ	‘bait’	blafogbe	‘pineapple’
drɛ	‘stretch arms’	edrɔ	‘dream’

exlɔ	‘friend’	exle	‘flea’
hlɛ	‘read’	ŋlɔ	‘write’
t^{ʃ}rɔ̃	‘exterminate’	ɲrã	‘be ugly’
klɔ	‘wash’	tre	‘glue’
vlu	‘stretch a rope’	lɔ	‘like’
mla	‘pound a drum’	pleplelu	‘laughing dove’
wla	‘hide’	zro	‘fly’
esrɔ	‘spouse’	etro	‘scale’
eɲrɔ̃	‘spitting cobra’	d^{ʒ}ro	‘hint’

7 Shambaa

Describe the distribution of voiced versus voiceless nasals (voiceless nasals are written with a circle under the letter, as in m̥), and voiceless aspirated, voiceless unaspirated and voiced stops in Shambaa.

tagi	‘egg’	kitabu	‘book’	paalika	‘fly!’
ni	‘it is’	ŋombe	‘cow’	matagi	‘eggs’
dodoa	‘pick up’	goʃa	‘sleep!’	babu	‘skin’
ndimi	‘tongues’	ŋgoto	‘heart’	mbeu	‘seed’
n̥t^{h}umbii	‘monkey’	ŋ̊k^{h}uŋguni	‘bedbug’	m̥p^{h}eho	‘wind’

8 Thai

The obstruents of Thai are illustrated below. Determine what the obstruent phonemes of Thai are ([p˺, t˺ and k˺] are unreleased stops). Are [p˺, t˺, k˺] distinct phonemes, or can they be treated as positional variants of some other phoneme? If so, which ones, and what evidence supports your decision? Note that no words begin with [g].

bil	‘Bill’	myy	‘hand’
rak˺	‘love’	baa	‘crazy’
loŋ	‘go down’	bryy	‘extremely fast’
haa	‘five’	plaa	‘fish’
dii	‘good’	t^{ʃ}aan	‘dish’
t^{h}ee	‘pour’	t^{h}ruumɛɛn	‘Truman’
k^{h}ɛŋ	‘hard’	panjaa	‘brains’
ləəj	‘pass’	p^{h}jaa	[title]
lyak˺	‘choose’	klaaŋ	‘middle’
t^{ʃh}at˺	‘clear’	traa	‘stamp’
riip˺	‘hurry’	ɔɔk˺	‘exit’
p^{h}rɛɛ	‘silk cloth’	kiə	‘wooden shoes’
k^{h}waa	‘right side’	kɛɛ	‘old’
draj	‘drive (golf)’	dyŋ	‘pull’
kan	‘ward off’	t^{ʃ}uək˺	‘pure white’
p^{h}leeŋ	‘song’	t^{ʃh}an	‘me’
staaŋ	‘money’	rap˺	‘take’
jiisip˺	‘twenty’	p^{h}aa	‘cloth’
k^{h}aa	‘kill’	dam	‘black’
raaj	‘case’	tit˺	‘get stuck’

sip̚	‘ten’	pen	‘alive’

9 Palauan

Analyse the distribution of *ð, θ* and *d* in the following data. Examples of the type ‘X ~ Y’ mean that the word can be pronounced either as X or as Y, in free variation.

kəðə	‘we (inclusive)’	bəðuk	‘my stone’
ðiak ~ diak	‘negative verb’	maθ	‘eye’
tŋoθ	‘tattoo needle’	ðe:l ~ de:l	‘nail’
ðiosəʔ ~ diosəʔ	‘place to bathe’	ðik ~ dik	‘wedge’
kuθ	‘louse’	ʔoðiŋəl	‘visit’
koaθ	‘visit’	eaŋəθ	‘sky’
ŋərarəðə	‘a village’	baθ	‘stone’
ieðl	‘mango’	ʔəðip	‘ant’
kəðeb	‘short’	məðəŋei	‘knew’
uðouθ	‘money’	olðak	‘put together’

10 Quechua (Cuzco dialect)

Describe the distribution of the following four sets of segments: k, x, q, χ; ŋ, ɴ; i, e; u, o. Some pairs of these segments are allophones (positional variants) of a single segment. You should state which contrasts are phonemic (unpredictable) and which could be predicted by a rule. For segments which you think are positional variants of a single phoneme, state which phoneme you think is the underlying variant, and explain why you think so; provide a rule which accounts for all occurrences of the predictable variant. (Reminder: ɴ is a uvular nasal.)

qori	‘gold’	t^{ʃ}oχlu	‘corn on the cob’
q’omir	‘green’	niŋri	‘ear’
moqo	‘runt’	hoq’ara	‘deaf’
p^{h}ul^{j}u	‘blanket’	jujaŋ	‘he recalls’
tul^{j}u	‘bone’	api	‘take’
suti	‘name’	oɴqoj	‘be sick!’
t^{ʃ}ilwi	‘baby chick’	t^{ʃh}it^{ʃ}iŋ	‘he whispers’
t^{ʃh}aɴqaj	‘granulate’	aɴqosaj	‘toast’
qet^{ʃ}uŋ	‘he disputes’	p’isqo	‘bird’
musoχ	‘new’	t^{ʃ}uŋka	‘ten’
jaɴqaŋ	‘for free’	t^{ʃ}ul^{j}u	‘ice’
q^{h}el^{j}a	‘lazy’	q’eɴqo	‘zigzagged’
t^{ʃ}eqaŋ	‘straight’	qaŋ	‘you’
noqa	‘I’	t^{ʃ}axra	‘field’
t^{ʃ}eχniŋ	‘he hates’	soχta	‘six’
aχna	‘thus’	l^{j}ixl^{j}a	‘small shawl’
qosa	‘husband’	qara	‘skin’
alqo	‘dog’	seɴqa	‘nose’
karu	‘far’	atoχ	‘fox’
qaŋkuna	‘you pl.’	pusaχ	‘eight’

t’eχwaj	‘pluck’	t^{ʃ}’aki	‘dry’
wateχ	‘again’	aŋka	‘eagle’
waχtaj	‘hit!’	haku	‘let’s go’
waqaj	‘tears’	kaŋka	‘roasted’
waxt^{ʃ}a	‘poor’	waleχ	‘poor’
t^{h}akaj	‘drop’	reχsisqa	‘known’

11 Lhasa Tibetan

There is no underlying contrast in this language between velars and uvulars, nor is there an underlying contrast between voiced and voiceless obstruents, nor between stops or fricatives *except* /s/, which exists underlyingly. State what the underlying segments are, and give rules which account for the surface distribution of these consonant types. (Notational reminder: [ɢ] represents a voiced uvular stop.)

aŋgu	‘pigeon’	aŋʈãã	‘a number’	aŋba	‘duck’
apsoo	‘shaggy dog’	amt^{ʃ}ɔɔ	‘ear’	tukʈyy	‘poison snake’
amto	‘a province’	ɨγu	‘uncle’	ɨmt^{ʃ}i	‘doctor’
uʈɨ	‘hair’	uβɪɪ	‘forehead’	eʁa	‘bells’
embo	‘deserted’	ʊʊt^{s}i	‘oh-oh’	qa	‘saddle’
qaʁa	‘alphabet’	qaŋba	‘foot’	qamba	‘pliers’
qam	‘to dry’	qamtoo	‘overland’	sarβo	‘steep’
kɨkʈi	‘belch’	kɨβu	‘crawl’	kɨɨŋguu	‘trip’
kik	‘rubber’	kiʈuu	‘student’	kɪɪcuu	‘translator’
kɪɪrii	‘roll over’	kiiγuu	‘window’	ku	‘nine’
kupt^{ʃ}ɨ	‘900’	kupt^{ʃ}aa	‘chair’	kɛnt^{ʃ}a	‘contract’
kɛmbo	‘headman’	keγøø	‘head monk’	kerβa	‘aristocrat’
qo	‘head’	qomba	‘monastery’	qɔr	‘coat’
qɔɔʁɔɔ	‘round’	t^{ʃh}eʁa	‘half’	t^{ʃh}uγum	‘cheese’
topcaa	‘stairs’	t^{h}oʁõõ	‘tonight’	ʈaaʁãã	‘post office’
ʈuγɨ	‘harbor’	ʈuɴɢo	‘China’	nɛɴɢaa	‘important’
paɴɢɔɔ	‘chest’	pɛɛβãã	‘frog’	simɢãã	‘build a house’

12 Kirzan Armenian

In this language, certain surface vowels can be predictably derived from other underlying vowels. Discover what vowels in this language are purely predictable, and give the rule which derives the predictable vowels.

t^{ʃ}iv	‘baby chicken’	d^{z}øʁi	‘bar’
met^{s}	‘big’	biʃt	‘bladder’
t^{s}it^{s}	‘breast’	jeχt^{sh}i	‘church’
kov	‘cow’	d^{z}æk^{h}	‘cub’
d^{ʒ}øk	‘distinction’	d^{z}y	‘egg’
əsking	‘fingernail’	kɑnɑnt^{ʃh}	‘green’
zijɑn	‘harm’	g^{j}ynd	‘heap’
t^{s}ɑk	‘hole’	tɑk^{h}	‘hot’

tun	‘house’	tʰɑkʰɑveɾ	‘king’
deʁin	‘yellow’	dænɑg	‘knife’
tʰətʰev	‘light (adj)’	ber	‘load’
mis	‘meat’	χeχtʃ	‘miserable’
poɾt	‘navel’	tʰi	‘oar’
pɑɾɑv	‘old woman’	dys	‘outside’
tˢeɾ	‘peak (n)’	bøχk	‘radish’
gʲet	‘river’	toɾon	‘Rubiaceae plant’
tˢov	‘sea’	tʃoɾt	‘servant boy’
gʲæɾ	‘sheep’	byɾd	‘snowstorm’
bæh	‘spade’	gʲøʁ	‘thief’
puk	‘throat’	χiʒ	‘tree gum’
døʁdøʁɑl	‘tremble’	dʒyɾ	‘water’
len	‘wide’	gʲil	‘wolf’

13 Logoori (advanced)

As studied in Chapter 2, Logoori has the phonetic vowels [i ɪ e ɛ a ɔ o ʊ u]. The online word recordings at https://languagedescriptions.github.io/IP3/Ch3.html provide you with a basis for determining which of the vowels [e ɛ o ɔ] must be underlyingly specified, and which can be derives by applying a rule. This exercise requires you to transcribe the data from the recordings, and assumes that you followed the analysis of vowel transcription in Ch. 2.

Further reading

Cohn 1993; Halle 1959; Harris 1994; Kahn 1976; Sapir 1925.