Introducing Phonology

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September, 2003

Penultimate draft: Comments welcome (odden@ling.ohio-state.edu)
To appear, Cambridge University Press

Foreword

This is an introductory textbook on phonological analysis, designed for a first course in phonology which assumes only a very general introduction to linguistics and phonological concepts. Insofar as it is a textook in phonology, it is not a textbook in phonetics (although it does include the minimum coverage of phonetics required to do basic phonology). The core of the book is intended to be used in an undergraduate introduction to phonology, and the chapters which focus specifically on analysis can be covered during a ten-week quarter. A brief and more intensive discussions of theoretical issues along with suggested readings is to found at the end of a number of chapters. The last two chapters, on abstractness and non-linear representations, focus on problematic theoretical issues that arise in analysing certain types of data, and thus provide both an introduction to some fundamental theoretical issues, as well as presenting an extended discussion of how data issues can influence theory. The chapter-end discussions and the more theoretical chapters are particularly designed for inclusion in a graduate course, where this text might serve as the main textbook and would be supplemented by readings and discussion of theoretical issues.

It is not the goal of this book to cover current theory. The main emphasis is developing foundational skills at analyzing phonological data. For this reason, there is significantly less emphasis on exposition of the various theoretical positions that phonologists have taken over the years. However, theory cannot be entirely avoided, nor would it be desireable to entirely avoid theoretical issues. As practicioners in the field will recognise, raw data makes no sense unless interpreted in the context of a theory about what we expect data to look like, thus analysis needs theory. Equally, theories are formal models which impose structure on data — theories are theories *about* data — so theories need data, hence analysis. The theoretical issues which are discussed herein are chosen because they are issues which have come up many times in phonology, because they are fundamental issues, and especially because they allow exploration of the deeper philosophical issues involved in theory construction and testing.

A number of colleagues have read and commented on versions of this book. I would like to that Lee Bickmore, Patrik Bye, Chet Creider, Sharon Hargus, Tsan Huang, Beth Hume, Keith Johnson, Ellen Kaisse, Susannah Levi, Marcelino Liphola, Mary Paster, Charles Reiss and especially Mary Bradshaw for their valuable comments. Andrew Winard and Juliet Berry-Davis have also provided valuable comments during the stage of final revisions. I would also like to thank students at the University of Western Ontario, University of Washigton, University of Tromsø, Ohio State University, Kyungpook National University, Concordia University and the 2003 LSA Summer Institute at MSU, for serving as a sounding board for various parts of this book.

Data from my own field notes provide the basis for a number of the examples, and I would like to thank my many language consultants for the data

which they have provided me, including Angas (Tamwakat Gofwen), Efik (Bassey Irele), Ga (Edward Amo), Hehe (John Mtenge and the late Margaret Fivawo), Kamba (Beatrice Mulala), Kenyang (Oben Ako), Kerewe (primarily Deo Tungaraza), Kimatuumbi (primarily Emmanuel Manday), Kipsigis (Matthew Kirui), Kotoko (Habi), Nkore (Patrick Bamwine), Shambaa (David Mndolwa), Shona (Kokerai Rugara), Sundanese (Udin Saud) and Tibetan (Nawang Nornang).

Finally, I would like to thank professional colleagues for providing me or otherwise helping me with data used in this book, including Grover Hudson (Amharic), Bert Vaux (Armenian), David Payne (Axininca Campa), Nasiombe Mutonyi (Bukusu), Anders Holmberg (Finnish), Lou Hohulin (Keley-i), Younghee Chung, Noju Kim, and Misun Seo (Korean), Chacha Nyaigotti Chacha (Kuria), Marcelino Liphola (Makonde), Karin Michelson (Mohawk), Ove Lorentz (Norwegian), Berit Anne Bals (Saami), Nadya Vinokurova (Sakha / Yakut) and Andrea Sims (Serbo-Croatian), all of whom are blameless for any misuse I have made their languages and data.

Languages

The following is a (partial) list of languages used in the text. The name of the language is given, followed by the genetic affiliation and location of the language, finally the source of the data. This list is crude, and does not yet include all languages used in the text or all sources drawn upon: this is being fixed. Genetic affiliation typically gives the lowest level of the language tree that is likely to be widely know, thus Bantu languages will be cited as "Bantu", and Tiv will be cited as "Benue-Congo", even though "Bantu" is a part of Benue-Congo and "Tiv" is a specific language in the Tivoid group of the Southern languages in Bantoid. Any inspirations about the best way to give useful genetic information will be appreciated. Locations will generally list one country but sometimes more; since language boundaries rarely respect national boundaries, it is to be understood that the listed country(s) are the primary locations where the language is spoken, or at least historically originates from (thus the Yiddish-speaking population of the US appears to be larger than that of any one country in Eastern Europe, due to recent population movements). Finally, please note that work on the list of sources is still in progress. The notation "FN" indicates that the data comes from my own field notes.

Akan [Volta-Congo; Ghana]: Dolphyne 1988.
Amharic [Semitic; Ethiopia]: Obolensky, Zelelie & Andualem 1964.
Angas [Chadic; Nigeria]: FN.
Arabela [Zaparoan; Peru]: Rich 1963
Aramaic (Azerbaijani) [Semitic; Azerbaijan]: Hoberman 198x.
Araucanian [Araucanian; Argentina, Chile]

Armenian [Indo-European; Armenia, Iran, Turkey]: Vaux 1998 and p.c.
Axininca Campa [Arawakan; Peru]: Payne 1981 and p.c.
Bedouin Hijazi Arabic [Semitic; Saudi Arabia]: Al-Mozainy 1981.
Bukusu [Bantu; Kenya]: Nasiombe Mutonyi p.c.
Catalan [Romance; Spain]: Kenstowicz & Kisseberth 1979.
Chamorro [Austronesian; Guam]. Topping 1968, Topping & Dungca 1973, Chung 1983.
Chukchi [Chukotko-Kamchatkan; Russia]: Krauss 1981.
Digo [Bantu; Kenya & Tanzania]: Kisseberth 1984.
Efik [Benue-Congo; Nigeria]: FN.
Etsako [Edoid; Nigeria]: Elimelech 1978.
Evenki [Tungusic; Russia]: Konstantinova 1964, Nedjalkov 1997, Bulatova & Grenoble 1999.
Ewe [Volta-Congo; Benin]: Clements 1978.
Farsi [Indo-European; Iran]: Obolensky, Panah & Nouri 1963
Finnish. [Uralic; Finland, Russia]: Whitney 1956, Lehtinen 1963.
Fula [West Atlantic; West Africa]: Paradis 1992.
Gã [Volta-Congo; Ghana]: FN in collaboration with Mary Paster.
Ganda [Bantu; Uganda]: Cole 1967, Snoxall 1967.
Greek [Indo-European; Greece]
Hebrew [Semitic; Israel]: Kenstowicz & Kisseberth 1979.
Hehe [Bantu; Tanzania]: FN in collaboration with Mary Odden.
Holoholo [Bantu; Congo]; Coupez 1955.
Hungarian [Uralic; Hungary]: Kenesei, Vago & Fenyvesi 1998.
Icelandic [Germanic; Iceland]: Einarsson 1945, Jónsson 1966, Oresnik 1985.
Japanese [Japanese; Japan]: Martin 1975.
Kamba [Bantu; Kenya]: FN in collaboration with Ruth Roberts-Kohno.
Karok [Hokan; USA]; Bright 1957.
Keleyi [Austronesian; Phillipines]: Kenstowicz & Kisseberth 1979.
Kenyang [Bantu; Cameroun]: FN.
Kera [Chadic; Chad]: Ebert 1975.
Kerewe [Bantu; Tanzania]: FN.
Kikuyu [Bantu; Kenya]: Clements 1984.
Kimatuumbi [Bantu; Tanzania]: FN.
Kipsigis [Nilotic; Kenya]: FN.
Klamath [Penutian; USA]: Barker 1963, 1964.
Kolami [Dravidian; India]: Emeneau 1961.
Korean [Korean; Korea]: Martin 1992; YH Chung, NJ Kim and M Seo p.c.
Koromfe [Gur; Bourkina Fasso]: Rennison 1997.
Kotoko [Chadic; Cameroun]: FN.
Kuria [Bantu; Kenya]: FN.
Lamba [Bantu; Zambia]: Doke 1938.
Lardil [Pama-Nyungan; Australia]: Klokeid 1976.

Latin [Indo-European; Italy]
Lithuanian [Indo-European; Lithuania]: Dambriunas et al. 1966, Ambrazas 1997, Mathiassen 1996
Lomongo [Bantu; Congo]: Hulstaert 1961.
Luluba [Nilo-Saharan; Sudan]: Andersen 1987.
Makonde [Bantu; Mozambique]: Marcelino Liphola p.c.
Maltese [Semitic; Malta]: Aquilina 1965, Borg & Azzopardi-Laexandre 1997, Brame 1972, Hume 1994.
Manipuri [Sino-Tibetan; India, Myanmar, Bangaladesh]: Bhat & Ningomba 1997.
Margyi [Chadic; Nigeria]: Hoffmann 1963.
Mende [Mande; Liberia, Sierra Leone]
Mixtec [Mixtecan; Mexico]: Pike 1948.
Mohawk [Hokan; USA]: Postal, Michelson.
Mongolian [Altaic; Mongolia]: Hangin 1968.
Nkore [Bantu; Uganda]: FN in collaboration with Robert Poletto.
Norwegian [Germanic; Norway]: Ove Lorentz p.c.
Ossetic [Indo-European; Georgia, Russia]: Abaev 1964, Whitley 1978.
Palauan [Austronesian; Palau]: Josephs 1975, Flores.
Polish [Slavic; Poland]: Kenstowicz & Kisseberth 1979.
Quechua (Cuzco) [Quechua; Peru]: Bills et al. 1969, Cusihuaman 1976.
Russian [Slavic; Russia]
Saami [Uralic; Sápmi (Norway, Sweden, Finland, Russia)]: Berit Anne Bals p.c.
Samoan [Austronesian; Samoa]: Milner 1966.
Serbo-Croatian [Slavic; Yugoslavia]
Setswana [Bantu; Botswana]: Cole 1955, Snyman, Shole & Le Roux 1990.
Shambaa [Bantu; Tanzania]: FN.
Shona [Bantu; Zimbabwe]: FN.
Slave [Athapaskan; Canada]. Rice 1989.
Slovak [Slavic; Slovakia]: Kenstowicz 1972, Rubach 1993.
Somali [Cushitic; Somalia]: Andrzejewski 1964, Kenstowicz 199X, Saeed 1993, Saeed 1999
Sundanese [Austronesian; Indonesia]: FN.
Syrian Arabic [Semitic; Syria]: Cowell 1964.
Tagalog [Austronesian; Phillipines]
Tera [Chadic; Nigeria]: Newman.
Thai [Daic; Thailand]
Tibetan [Sino-Tibetan; Tibet]: FN.
Tiv [Benue-Congo; Nigeria]
Tohono ʼOʼodham [Uto-Aztecan; USA]
Tonkawa [Coahuiltecan; USA]: Hoijer 1933.
Turkish [Altaic; Turkey]
Ukranian (Sadžava, Standard) [Slavic; Ukraine]: Carlton 1971, Press & Pugh 1994 (Standard). Popova 1972 (Sadžava).

Vata [Kru; Côte d'Ivoire]: Kaye 1982.
Votic [Uralic; Russia]: Ariste 1968.
Warao [Warao; Venezuela]
Wintu [Penutian; USA]: Pitkin 1984.
Woleaian [Austronesia; Micronesia]: Sohn 1975.
Yakut [Altaic; Russia]: Krueger 1962.
Yawelmani [Penutian; USA]. Newman 1944.
Yiddish [Germanic; Eastern Europe]
Yoruba [Kwa; Nigeria]: Akinlabi 1984.

How to use this book

Look words up in the glossary at the back if you don't know the word.

Look symbols up in the table if you forget what they mean.

Especially, learn the phonetic classifications of sounds, because there's nothing worse than puzzling over how to express a rule that applies before the soulds {k,g,x,γ,ŋ} if you forget the meaning of the term "velar".

<<this part needs to be written and the appendices need to be actually done>>

1

What is phonology?

This chapter introduces phonology, the study of the sound systems of language. Its key objective is to:

- Introduce the notion of phonological rule
- Explain the nature of sound as a physical object
- Highlight the tradeoff between accuracy and usefulness in representing sound
- Distinguish between phonetics and phonology
- Contrast the continuous and discrete aspects of linguistic sounds
- Introduce the notion of "sound as cognitive symbol"

Phonology is one of the core fields that composes the discipline of linguistics, which is defined as the scientific study of language structure. One way to understand what the subject matter of phonology is, is to contrast it with other fields within linguistics. A very brief explanation is that phonology is the study of sound structure in language, which is different from the study of sentence structure (syntax) or word structure (morphology), or how languages change over time (historical linguistics). This definition is very simple, and also inadequate. An important feature of the structure of a sentence is how it is pronounced — its sound structure. The pronunciation of a given word is also a fundamental part of the structure of the word. And certainly the principles of pronunciation in a language are subject to change over time. So the study of phonology eventually touches on other domains of linguistics.

An important question is how phonology differs from the closely related discipline of phonetics. Making a principled separation between phonetics and phonology is difficult — just as it is difficult to make a principled separation between physics and chemistry, or sociology and anthropology. A common characterization of the difference between phonetics and phonology is that phonetics deals with 'actual' physical sounds as they are manifested in human speech, such as acoustic waveforms, formant values, duration measured in milliseconds, measurements of amplitude and frequency, or in the physical principles underlying the production of sounds, which involves the study of resonances and the study of the muscles and other articulatory structures used to produce these physical sounds.

On the other hand, phonology, it is said, is a more abstract cognitive system dealing with rules in a mental grammar, that is, principles of subconscious 'thought' as they relate to language sound. Yet once we look into the central questions of phonology in greater depth, we will find that the boundaries between the disciplines of phonetics and phonology are not entirely clear-cut. As research in both of these fields has progressed, it has become apparent that a better understanding of many issues in phonology requires one to bring phonetics into consideration, just as a phonological analysis is a prerequisite for any phonetic study of language.

1. Concerns of Phonology

As a step towards understanding what phonology is, and especially how it differs from phonetics, we will consider some specific aspects of sound structure that would be part of a phonological analysis. The point which is most important to appreciate at this moment is that the 'sounds' which phonology is concerned with are symbolic sounds — they are cognitive abstractions, which represent physical sounds.

The sounds of a language. One aspect of phonology considers what the 'sounds' of a language are. We would want to take note in a description of the phonology of English that we lack a particular vowel that exists in German in words like *schön* 'beautiful', a vowel which is also found in French (spelled *eu*, as in *jeune* 'young'), or Norwegian (*øl* 'beer'). Similarly, the consonant spelled *th* in English *thing*, *path* is found in English (as well as in Icelandic where it is spelled with the letter *þ*, or Modern Greek where it is spelled with *θ*, or Saami where it is spelled *ŧ*), but this sound does not occur in German or French, and it is not used in Latin American Spanish, although it does occur in Continental Spanish in words such as *cerveza* 'beer', where by the spelling conventions of Spanish, the letters *c* and *z* represent the same sound as the one spelled *θ* (in Greek) or *th* (in English).

Rules for combining sounds. Another aspect of language sound which a phonological analysis would take account of is that in any given language, certain combinations of sounds are allowed, but other combinations are systematically impossible. The fact that English has the words *brick*, *break*, *bridge, bread* is a clear indication that there is no restriction against having words begin with the consonant sequence *br*; besides these words, one can think of many more words beginning with *br* such as *bribe, brow* and so on. Similarly, there are many words which begin with *bl,* such as *blue*, *blatant, blast, blend, blink*, showing that there is no rule against words beginning with *bl*. It is also a fact that there is no word **blick*[1] in English, even though the similar words *blink, brick* do exist. The question is, why is there no word **blick* in English? The best explanation for the nonex-

[1] The asterisk is used to indicate that a given word is non-existent or wrong.

istence of this word is simply that it is an accidental gap — that not every logically possible combination of sounds which follows the rules of English phonology is found as an actual word of the language.

Native speakers of English have the intuition that while *blick* is not actually a word of English, it is a theoretically possible word of English, and such a word might easily enter the language, for example via the introduction of a new brand of detergent. 50 years ago the English language did not have any word pronounced *bick*, but based on the existence of words like *big* and *pick*, that word would certainly have been included in the set of nonexistent but theoretically allowed words of English. Contemporary English, of course, actually does contain that word — spelled *Bic* — which is a type of pen.

While the nonexistence of a word *blick* in English is an accidental gap, there are many other imaginable but nonexistent words whose exclusion from English is based on a principled restriction of the language. While there are words that begin with *sn* like *snake, snip* and *snort*, there are no words beginning with *bn*, and thus **bnick, *bnark, *bniddle* are not words of English: there simply are no words in English which begin with *bn*. Moreover, native speakers of English have a clear intuition that hypothetical **bnick, *bnark, *bniddle* simply could not be words of English. Similarly, there are no words in English which are pronounced with *pn* at the beginning, a fact which is not only demonstrated by the systematic lack of words such as **pnark, *pnig, *pnilge*, but also by the fact that the word spelled *pneumonia* which derives from Greek (a language which does allow such consonant combinations) is pronounced without *p*. A description of the phonology of English would then provide a basis for characterising such restrictions on sequences of sounds.

Variations in pronunciation. In addition to providing an account of possible versus impossible words in a language, a phonological analysis will explain other general patterns in the pronunciation of words. For example, there is a very general rule of English phonology which dictates that the plural suffix on nouns will be pronounced as [ɨz], represented in spelling as *es*, when the preceding consonant is one of a certain set of consonants including [š] (spelled *sh*) as in *bushes*, [č] (spelled as *ch*) as in *churches*, and [ǰ] (spelled *j, ge, dge*) as in *cages, bridges*. This pattern of pronunciation is not limited to the plural, so despite the difference in spelling, the possessive suffix *s*[2] is also subject to the same rules of pronunciation: thus, plural *bushes* is pronounced the same as the possessive *bush's*, and plural *churches* is pronounced the same as possessive *church's*.

This is the sense in which phonology is about the sounds of language. From the phonological perspective, a 'sound' is a specific unit which combines with other such specific units, and which represent physical sounds.

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[2] This is the 'apostrophe s' suffix found in "The child's shoe", meaning "shoe owned by the child".

2. Phonetics — What is Physical Sound?

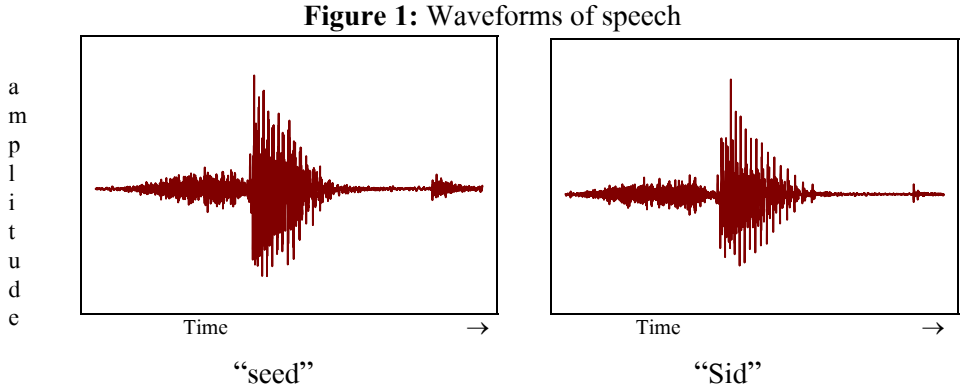
Phonetics, on the other hand, is about the concrete, instrumentally measurable physical properties and production of these cognitive speech sounds. That being the case, we must ask a very basic question about phonetics (one which we also raise about phonology). Given that phonetics and phonology both study 'sound' in language, what *are* sounds, and how does one *represent* the sounds of languages? The question of the physical reality of an object, and how to represent the object, is central in any science, and if we have no understanding of the physical reality, we have no way of talking meaningfully about it. Before deciding *how* to represent a sound, we need to first consider *what* a sound is. To answer this question, we will look at two basic aspects of speech sounds as they are studied in phonetics, namely **acoustics** which is the study of the properties of the physical sound wave that we hear, and **articulation**, which is the study of how to modify the shape of the vocal tract, thereby producing a certain acoustic output (sound).

2.1. Acoustics

A 'sound' is a complex pattern of rapid variations in air pressure, traveling from a sound source and striking the ear, which causes a series of neural signals to be received in the brain: this is true of speech, music and random noises.

Waveforms. A concrete way to visually represent a sound is with an acoustic **waveform**. A number of computer programs allow one to record sound into a file and display the result on the screen. By this means one can visually inspect a representation of the physical pattern of the variation in air pressure. Figure 1 gives the waveforms of a particular instance of the English words *seed* and *Sid*.

Figure 1: Waveforms of speech



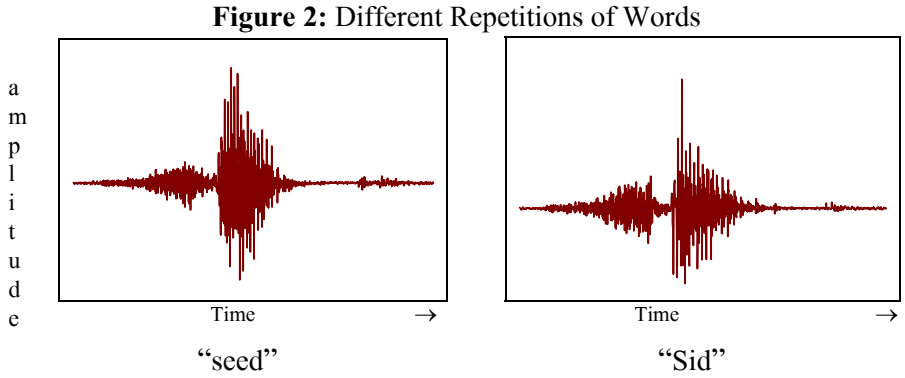
The horizontal axis represents time, with the beginning of each word at the left and the end of the word at the right. The vertical axis represents displacement of air

particles and correlates with the variations in atmospheric pressure that affect the ear. Positions with little variation from the vertical center of the graph represent smaller displacements of air particles, such as the portion that almost seems to be a straight line at the right side of each graph. Such minimal displacements from the center correspond to lower amplitude sounds. The portion in the middle where there much greater vertical movement in the graph indicates that the sound at that point in time has higher amplitude. While such a direct representation of sounds is extremely accurate, it is also fairly uninformative.

Absolute accuracy is impossible, both in recording and measurement. Scientific instruments discard information: microphones have limits on what they can capture, as do recording or digitizing devices. Any representation of a sound is a measurement, which is an idealisation about an actual physical event

The difference between these words lies in their vowels (*ee* versus *i*), which is the part in the middle that where the fluctuations in the graph are greatest. It is difficult to see a consistent difference just looking at these pictures — though since these two vowels are systematically distinguished in English, it cannot be impossible. It is also very difficult to see similarities looking at actual waveforms. Consider Figure 2 which gives different repetitions of these same words by the same speaker.

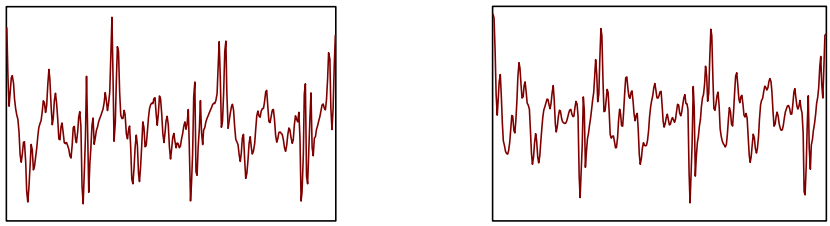
Figure 2: Different Repetitions of Words



Visual inspection gives you no reason to think that these sets of graphs are the same words said on different occasions. The problem is that while a physical waveform is a very accurate representation of the words, it provides so much information that we cannot tell what is important and what is not.

Since we are interested in the part which makes these two words sound different, we might get a clearer picture of the physical difference by expanding the scale and looking just at a part of the vowel. Vowels are **periodic**, which means that the pattern of their waveform repeats over time. The display in Figure 3 gives a portion of the vowels from the middle of the words *seed* and *Sid*, involving around 20 milliseconds (ms) of each of the words (the entire word in each of these two examples actually lasts approximately 500 ms, so this is a small part of the entire word). We can indeed see that there is a pattern which is repeated (although successive repetitions are not perfect reproductions).

FIGURE 3: Waveform of *seed, Sid*



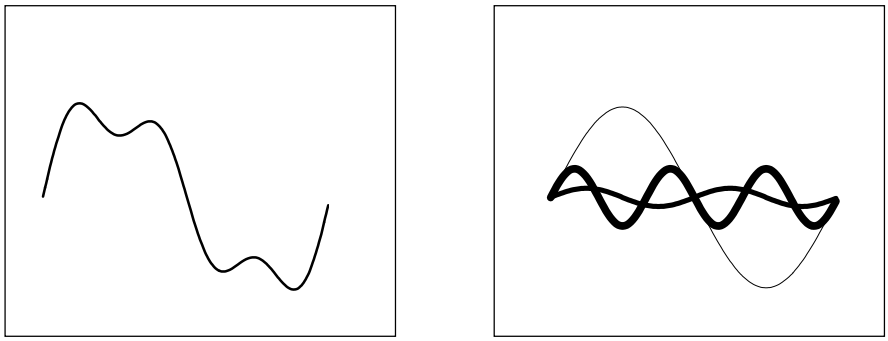
seed Sid

Though there are visible differences between the waveforms, the basis for distinguishing these vowels remains unclear.

Sound spectra. We need a better analytical technique than just looking at raw sound, to be able to talk precisely about properties of these sounds. We therefore need to understand some basic properties of physical sounds. All sound waves are definable in terms of three properties that characterise a **sine wave** familiar from trigonometry, namely **frequency** measured in cycles per second also known as Hertz (Hz), **amplitude** measured in decibels (dB), and **phase** measured in the angular measure radians. These characteristics suffice to define any sine wave, which is the analytic basis of sounds. The property phase, which describes how far into the infinite cycle of repetition a particular sine wave is, turns out to be unimportant for the study of speech sounds, so it can be ignored. Simple sine waves (termed 'pure tones' when speaking of sounds) made up of a single frequency are not commonly encountered in the real world, but can be created by a tuning fork or by electronic equiptment.

Speech sounds (indeed all sounds) are complex waveforms which are virtually impossible to describe on their own terms. Fortunately, a complex waveform can be mathematically related to a series of simple waves which have different amplitudes at different frequencies (and phases), so that we can say that a complex waveform is 'built from' a set of simple waves. Figure 4 shows a complex wave on the left which is constructed mathematically by just adding together the three simple waveforms of different frequencies and amplitudes that you see on the right.

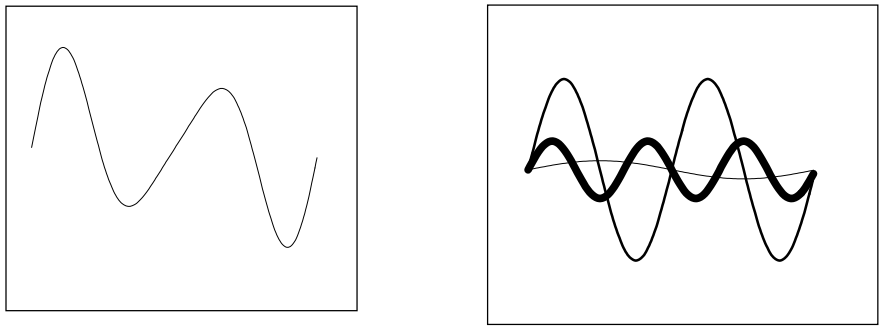
FIGURE 4: Complex wave and the component simple waves defining it



The complex wave on the left is made from simple sine waves at 100, 200, and 300Hz, and the individual components defining the complex wave are graphed on the right. The most prominent component (the one with the highest amplitude) is the one at 100 Hz, the thinnest line which makes one cycle in the chart: it has an amplitude of 60 dB. By comparison, the component at 200 Hz (graphed with a medium-weight line, which makes two cycles in the chart on the right) has the lowest amplitude, 50 dB. The 300 Hz component, graphed with the thickest line, has an intermediate amplitude of 50 dB. It is the amplitudes of the individual components which determine the overall shape of the resulting complex wave.

Now we will see what happens when we change this artificial sound to make the 200 Hz component be the most prominent component and the 100 Hz one be less prominent — if we simply switch the amplitudes of the 100 Hz and 200 Hz components, we get the wave Figure 5.

FIGURE 5: Effect of changing component amplitude

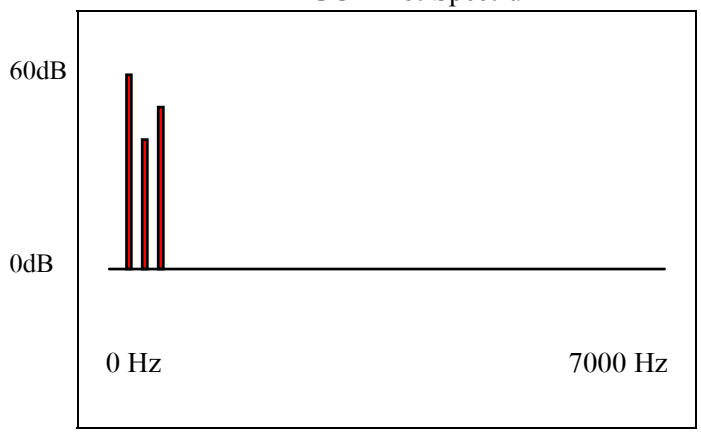


Changing the amplitude of one such component changes the overall character of the waveform. A complex wave is mathematically equivalent to a corresponding series of sine wave components, so describing a complex wave directly is equivalent to describing the individual components. If we see two differently-shaped

complex waves and we can't describe their differences directly in terms of the complex waves themselves, we can instead focus on the equivalent series of sine wave components, and describe the differences in terms of very simple information about differences in frequency and amplitude of components.

Just as a single complex waveform can be constructed mathematically from a series of simple waves at different frequencies and amplitudes, a single complex waveform can also be mathematically broken down into a series of components which have different frequencies and amplitudes. Rather than graph the full shape of each specific sine wave component — which becomes very hard to understand if there are more than a handful of components — we can simply graph the two important values for each of the component sine waves, the amplitude and frequency. This is known as a **spectrum**: it is the defining frequency and amplitude components of a complex waveform, over a fixed period of time. The spectrum of the waveform in Figure 4 is plotted in Figure 6, where the horizontal axis corresponds to frequency from 0 to 7,000 Hz and the vertical axis corresponds to amplitude from 0 to 60 dB. Note that in this display, time is not represented: the spectrum simply describes amplitude and frequency, and information about how long a particular complex waveform lasts would have to be represented somewhere else.

FIGURE 6: Spectrum

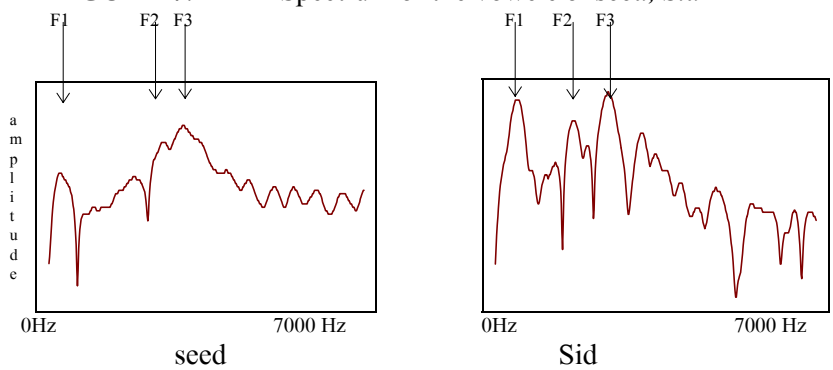


This is a very simple spectrum, representing an artificially constructed sound containing only three components. Naturally occurring sounds have many more components than this.

Since complex sounds can be mathematically broken down into a series of simple components, we can use this very useful tool to look at the vowel sounds of *seed* and *Sid*: we look at the physical properties of the component frequencies that define the two vowels that we were interested in. Figure 7 provides the spectrum of the portion from the middle of the vowels of *Sid* and *seed* which we looked at in Figure 3. The horizontal axis again represents frequency, ranging from 0 to 7000

Hz, and the vertical axis represents amplitude in decibels. Here, the spectrum is represented as a continuous set of amplitude values for all frequencies in this frequency range, and not just 5 discrete frequencies as seen in the constructed sound of Figure 6.

FIGURE 7: Spectrum of the vowels of *seed, Sid*



In these spectra, certain frequency regions are more prominent than others, due to **resonances** in the vocal tract. Resonances are frequency regions where sound amplitude is enhanced. These frequencies are perceptually more prominent than other lower-amplitude frequencies. The frequencies at which these resonances occur is related to the length of various parts of the vocal tract (ultimately related to the position of the tongue and lips as specific sounds are made). The relation between size and frequency is simple and familiar: a large bottle has a low resonance frequency and a small bottle has a higher resonance frequency. The first three of these prominent frequency regions, called **formants**, are indicated with pointed vertical lines in the graphs. You can see that in the spectrum for *seed* on the right, the first formant (F1) occurs at a lower frequency than does the first formant of the vowel in *Sid*. However, the second and third formants (F2, F3) of *seed* occur at somewhat higher frequencies than do F2 and F3 of *Sid*. By comparing the frequencies at which these formants occur, one can begin to systematically describe the physical properties of the vowels in *seed* and *Sid*. One of the most important properties which allows a listener to distinguish speech sounds, such as the vowels of "seed" versus "Sid", is the frequencies of these formants.

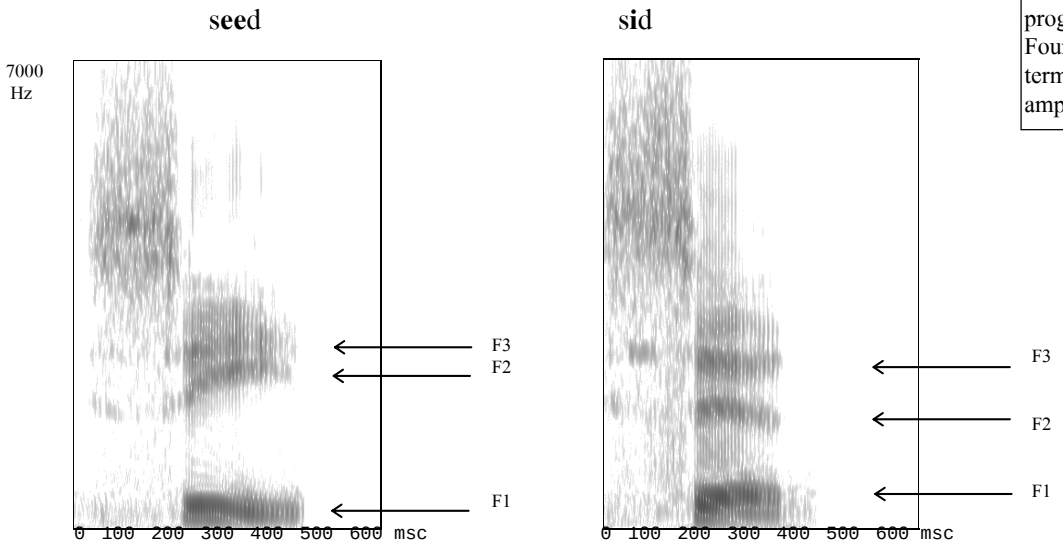
Viewing the waveform versus the spectrum of a sound involves a trade-off between accuracy and usefulness. While the spectrum is more informative since it allows us to focus on certain specific properties (formant frequencies), it is a less accurate representation of reality than the original waveform. Another very significant limitation of this type of spectral display is that it only characterizes a single brief moment in the utterance: speech is made up of more than just little 20 millisecond bits of steady sound. We need to include information about changes over time in a sound.

Inaccuracy in spectral data has three main sources. Half of the information in the original signal, phase, has been discarded. Frequency information is only approximate and is related to how much speech is analysed. Finally, a spectrum assumes that sound properties are constant during the period being analysed. If too large a piece of speech is taken for analysis, a misrepresentative blending of a continuously changing signal results.

Spectrograms. Another display, the **spectrogram**, shows both frequency and amplitude properties as they change over time, by adding a third dimension of information to the display. Figure 8 provides spectrograms of the entirety of the two words *seed* and *Sid*. In this display, the horizontal axis represents the time dimension where the utterance begins at the left and ends at the right. The vertical axis represents frequency information, lower frequencies appearing at the bottom and higher frequencies at the top. Amplitude is represented as darkness: higher amplitudes are darker and lower amplitudes are lighter.

A spectrogram can be made by a mechanical spectrograph, which uses an adjustable filter to select different frequency ranges and display the changes in amplitude at each frequency range; or, it can be created by a computer program, which uses Fourier analysis to determine these component amplitudes.

FIGURE 8: Spectrograms



The initial portion of the spectrogram represents the consonant *s*, and the second portion with the series of minute vertical striations represents the vowel (the consonant *d* is visible as a broad but short, light horizontal band at around 400 ms near the lower righthand corner of *Sid*, and is not visible at all in this example of *seed*). The formants which characterize the difference between the vowels of *seed* and *Sid* are represented as dark bands, the first formant being the darker lower band and the second and third formants being the two lighter bands appearing approximately one-third of the way up the display. The third formant in the word *seed* is somewhat hard to distinguish from the second formant in this display.

Looking at these spectrograms, we learn two other things about these vowels that we would not have suspected from looking at the spectrum in Figure 7 taken from a single point in time. First, notice that the vowel portion of *seed* is much longer than in *Sid*. Second, the frequencies of the formants change over time, so in *seed* the first two formants start out much closer together than they do in *Sid*, and then in *seed* the second formant rises over the first half of the vowel whereas in *sid* where the second formant falls.

A spectrogram is a reasonably informative and accurate display of properties of sound. It is less accurate than the spectrum at a single point, such as Figure 7. A spectrogram is nothing more than a series of such spectra, where the more detailed amplitude information represented on the vertical axis in Figure 7 is simplified to a less detailed and less reliable visual difference in darkness. It is also inefficient as a representation of the sound in two ways. First, as represented on a computer, it is bulky in comparison to a waveform, so that the above spectrogram is around eight times the size of the original waveform. Second, it is still difficult to interpret. While one can learn how to read a spectrogram of a word in a familiar language, and be fairly certain from inspecting certain properties of the display what word the spectrogram represents, even the most skilled of spectrogram readers require tens of seconds to interpret the display; the average person who has learned the basics of spectrogram reading would require a number of minutes and may not be able to correctly identify the utterance at all. Another limitation of the spectrogram is that, at least until recently, they required expensive specialized machinery to produce (machinery which did not exist until after World War II). The recent proliferation of inexpensive personal computers potentially brings spectrographic analysis into the hands of many more people, but nevertheless, good and inexpensive spectrogram software is not easy to find; and in many economically disadvantaged parts of the world, computers are an extreme luxury. It is therefore quite impractical to base the scientific study of language sound systems exclusively on spectrograms.

2.2. Articulation

Another way to analyse speech sounds is in terms of the arrangement of **articulators** — the lips, tongue and other organs of the vocal tract required to produce a particular speech sound. By appropriate positioning of articulators, the shape of the vocal tract can be changed, and consequently the sound which emerges from the vocal tract can be changed (much as different sized bottles produce different tones when you blow across the top). For the purpose of studying the production of speech, the most important articulators are the lips, teeth, tongue, palate, velum, pharynx and larynx.

Figure 9 illustrates the anatomical landmarks which are most important for the study of speech production.

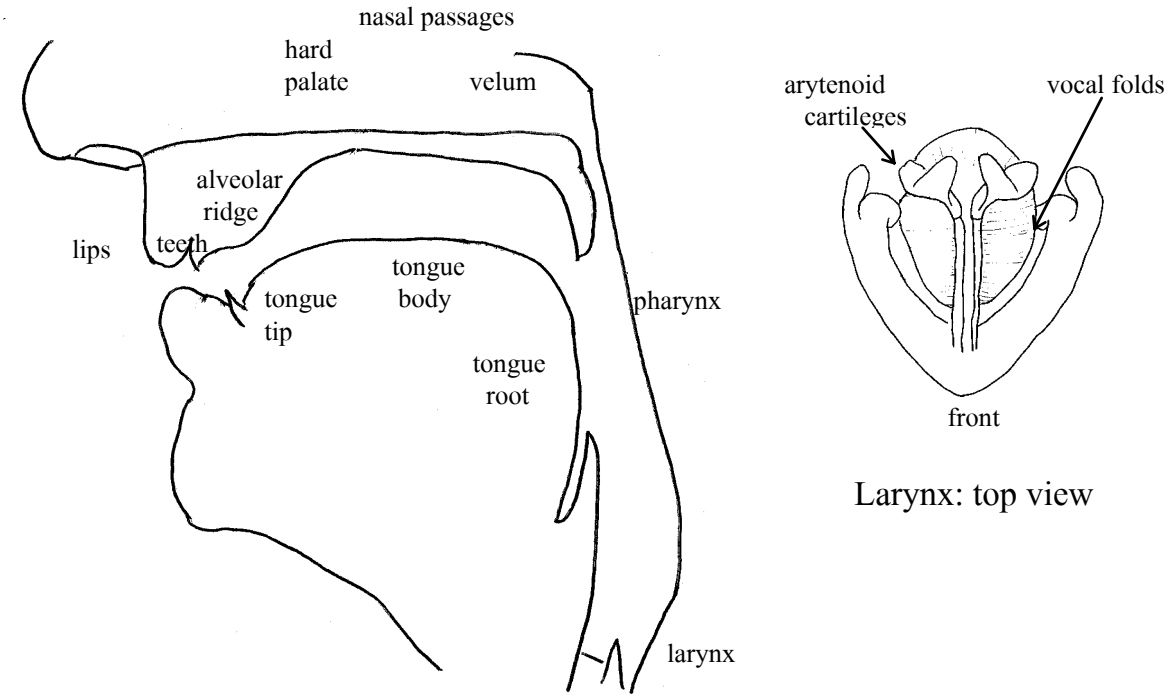


Figure 9: Speech Anatomy

Because sound production involves the manipulation of airflow, production of speech generally begins with the lungs which drive the air coming out of our mouths. Air is forced out of the lungs through the vocal folds, which acts as a valve that goes through a repeated cycle of allowing air to pass from the lungs to the vocal tract, versus blocking the flow of air. This repeated movement of air would produce a waveform that looks something like Figure 10, which represents air flow through the vocal folds when a voiced sound (such as a vowel) is produced.

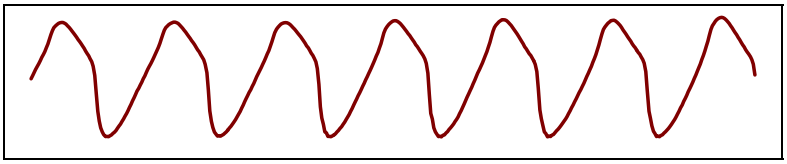


FIGURE 10: Airflow through glottis

This wave is further shaped by the geometry of the vocal tract, which emphasizes certain frequencies and supresses others. Thus the particular tongue shape that is characteristic of the vowel in *seed* — a higher and fronter position of the

tongue — is responsible for the acoustic difference between that vowel and the vowel of *Sid*.

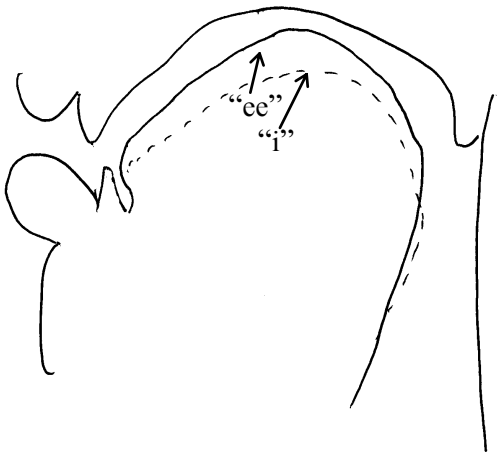


Figure 11: Tongue position differences between "ee" and "i"

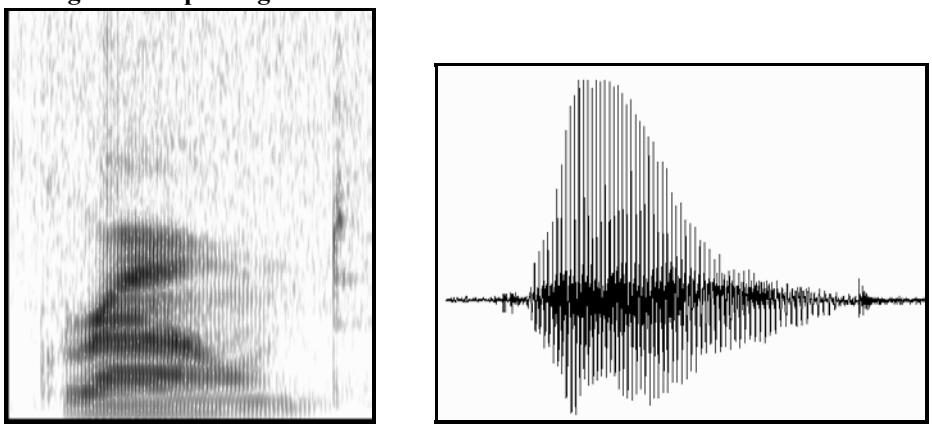
It is a general principle of physics that a longer tube has a lower resonating frequency than a shorter tube. The vocal tract can be treated as as a series of tubes, where the resonance frequencies of different tubes correspond to different frequencies of formants. By placing the tongue in various positions or by protruding the lips, sections of the vocal tract are lengthened or shortened, and thus their resonating frequencies — formant frequencies — are lowered or raised. For example, the length of the vocal tract in front of the constriction formed with the tongue determines the frequency of the second formant. When the tongue is advanced as it is for the vowel in *seed*, the portion of the vocal tract in front of the tongue is rather short, and therefore this front part of the vocal tract has a high resonating frequency: and thus the vowel has a high value for F2. On the other hand, the vowel in "pool" is produced with the tongue positioned further back, which means that the part of the vocal tract in front of the tongue is relatively long — it is made even longer because when [u] is produced, the lips are also protruded, which lengthens the entire vocal tract. The effect of lengthening the front part of the vocal tract is that the resonating frequency is lowered, and thus the vowel in "pool" has a very low value of F2.

How vocal tract shape determines the acoustic output is the domain of phonetics. While the acoustic and articulatory properties of speech are important in understanding phonology, indeed constitute the foundation on which phonology is built, it is just that — the foundation. Phonology looks at how these physical aspects of manifested speech are represented as part of the mental entity 'language'.

3. The symbolic representation of speech

The English word ‘ground’ is composed of six letters, and by happy coincidence, six distinct phonological sounds or, as they are called by phonologists, **segments**. But an inspection of what we can measure objectively in the acoustic signal, such as found in a spectrogram, shows no such clear physical boundaries in the stream of sound pointing to exactly six distinct sound events. Instead, we find a continuously changing stream of sound patterns, with the amplitude of the signal being stronger at a given time at certain frequencies than at others — corresponding to formant frequencies — where the frequencies of these peaks are constantly changing. For example, looking at the spectrogram in Figure 12, one can see a sliver of a darker area in the lower quarter at the very left edge of the spectrogram, which is followed by a light area, and then a pattern of closely spaced vertical striations. Below the spectrogram, one can see arrows giving approximate indications where each segment begins and ends, and this initial dark sliver followed by a light sliver constitutes the acoustic energy of the initial consonant [g]. While there seems to be a relatively clear break between the initial [g] and the following [r], the same cannot be said for any of the other adjacent sounds in this word.

Figure 12: Spectrogram **Acoustic Waveform**



^g ^ r ^ æ ^ w ^ n ^ d ^

This points to one of the most basic properties of phonology, and clarifies another essential difference between phonetics and phonology. Phonetics studies language sound as a continuous property. A phonological analysis relies on an important idealization of language sound, that the continuous speech signal can be analysed as a series of discrete segments with constant properties. It is evident, looking at the portion of the spectrogram corresponding to “r”, that the physical properties of the “r” change continuously over time — this is true of the entire spectrogram. Yet the transcription simply indicated a single unit “r”, implying a

clear beginning and end, and not suggesting that there is time-varying structure within "r".

Both phonetics and phonology involve representations of sound. A phonetic representation can be given as a series of numbers, representing the three acoustic essentials — amplitude, frequency and time — or as an analogous description of the complex and continuously changing internal geometry of the vocal tract. Such a representation would be highly accurate, and is appropriate if the goal is to understand the fine-grained details of speech sounds as physical objects. For the purposes of grammar, physical sound contains way too much information to allow us to make meaningful and general statements about language sound, and we require a way to represent just the essentials of language sounds. A phonological representation of an utterance reduces this great mass of phonetic information to a cognitively-based minimum, a sequence of discrete segments.

The basic tool behind this conversion of the continuous stream of speech sound into units is the phonetic transcription. The philosophy behind a transcription is that one can adequately represent all of the linguistically important details of an utterance by symbols whose interpretation is predefined. Phonology then can be defined as the study of higher-level patterns of language sound, conceived in terms of discrete and simple mental symbols, whereas phonetics can be defined as the study of how those mental symbols are physically manifested as continuous muscular contractions and acoustic waveforms.

By way of introduction to the nature of a symbolic transcription, let us take the case of the word 'ground' given above. The spelling 'ground' is a poor representation of the pronunciation of the word, for scientific purposes. If one were to follow rules for pronunciation in other languages such as Portuguese, Spanish or Italian, one might think that the word spelled 'ground' would be pronounced like 'groaned'. The problem with spelling is that the letter sequence 'ou' is pronounced in one way in Portuguese, another way in French (the word would be pronounced more like "grooned" if French pronunciation rules were followed), and a third way according to English rules. We need a system for representing sounds which is neutral with respect to the choice of language being studied — a system which could be used to discuss not only languages with a long written history like Greek or Chinese, but also languages like Ekoti (a Bantu language spoken in Mozambique) which remains to this day largely unwritten.

In addition, English spelling is imprecise in many cases. The consonant in the middle of "ether" is not the same as the one in the middle of the word "either" (if it were, these words would be pronounced the same, and they are not). English has two distinct kinds of "th" sound, but both are represented the same way in spelling. Linguists adopt special symbols which are better suited to accurately representing speech in an objective manner, so that anyone who knows the pronunciation of the symbols could pronounce a word of English (or Portuguese, Chinese, or Ekoti) written using those symbols with a high degree of accuracy. Thus, we

would represent the word ‘ground’ (as spoken by this author) as [græwnd], where [æ] represents the vowel found in ‘hat’.

The goal of phonology is not to provide accurate symbolic representations of speech. Rather, the goal is to understand the linguistic rules which operate on sounds mentally represented as symbols, and the transcription is our means of representing the data which we discuss. As it happens, the transcription [græwnd] does not really tell the scientist everything they need to know, in order to pronounce this word the same way as in Figure 12. A transcription is, essentially, a measurement of a physical phenomenon, and like all measurements can be made with greater or less precision. This particular transcription is quite sufficient for most purposes (such as a phonetic dictionary of English, where knowledge of the systematic principles of the language’s sound system might be assumed to be known). A more precise transcription such as [kɹʷæ̃:w̃nd] could be required for another purpose, such as conveying information about pronunciation independent of general knowledge of rules of phonetic realization that exist in English.

Interestingly, humans (especially standup comics) *are* capable of producing sounds which we understand as representing such sounds, even though they are not the actual sounds themselves. Even such sounds-representing-sounds are not part of the set of human speech sounds.

The very idea of trying to render a highly information-rich structure such as an acoustic waveform in terms of a rather small repertoire of discrete symbols is based on a very important assumption, one which has proven to have immeasurable utility in phonological research, namely that there are systematic limits on what constitutes a possible speech sound in human language. Some such limitations may be explained in terms of physical limits on the vocal tract, so humans are not physically capable of producing the sound emitted by a dentist’s high-speed drill, nor can humans produce the sound of a ton of dynamite exploding, but even restricting our attention to sounds which can be produced by the human vocal tract, there are very many sounds which humans can produce which are nevertheless not part of language. The basis for this limitation on speech sounds will be taken up in more detail in later chapters.

Summary

Phonetics and phonology both study language sound. Phonology examines language sound as a mental unit, encapsulated symbolically for example as [æ] or [g], and focuses on how these units function in grammars. Phonetics examines how symbolic sound is manifested as a continuous physical object. The conversion from physically continuous event to symbolic representation requires focusing on the information that is important, which is possible because not all physical properties of speech sounds are cognitively important. One of the goals of phonology is then to to discover exactly what these cognitively important properties are, and how they function in expressing regularities about languages.

Exercises

These exercises are intended to be a framework for discussion of the points made in this chapter, rather than being a test of knowledge and technical skills.

1. Examine the following true statements and decide if each best falls into the realm of phonetics or phonology.

a. The sounds in the word "frame" change continuously.
b. The word "frame" is composed of four segments.
c. Towards the end of the word "frame", the velum is lowered.
d. The last consonant in the word "frame" is a bilabial nasal.

2. Explain what a "symbol" is; how is a symbol different from a letter?

3. Give four rules of the phonological system of English, other than the ones already discussed in this chapter. Important: these should be rules about segments in English and not about spelling rules.

4. How many segments (not letters) are there in the following words (in actual pronunciation)?

sit	trap	fish
bite	ball	up
ox	through	often

5. Why would it be undesirable to use the most accurate representation of a spoken word that can be created under current technology in discussing rules of phonology?

Suggestions for further reading

A more detailed introduction to issues in linguistic phonetics can be found in Ladefoged 2001. Fry 1979 provides a good foundation in topics of physics relevant to understanding acoustics, such as the nature of waves and resonances. For a basic survey of the issues in acoustics which are important to the study of language sound, as well as an introduction to the topic of sound perception, see Johnson 1997. A more advanced treatment of acoustics is presented in Stevens 1998. Zemlin 1981 gives an extensive account of anatomy of the articulatory organs for speech, and Levelt 1989 covers articulation (the cognitive aspects of controlling the movement of speech organs). Kelly & Local 1989 discuss techniques for transcribing speech and in particular the varying degrees of detail that may be provided in a transcription. Finally, Liberman 1983 discusses some general issues relating to the distinction between phonetics and phonology.

2

Phonetic Transcriptions

This chapter gives an overview of phonetic transcriptions. It:

- Gives the important transcriptional symbols
- Introduces the two major schemes of phonetic transcriptions
- Presents the main articulatory classifications of sounds
- Surveys the main variations in phonetic properties exploited by languages
- Further developes the relevance of phonetics for the study of phonology

In phonetic transcription, speech is represented by a small set of symbols with a standard interpretation. This chapter looks at the different systems for phonetic transcription. There are two major schemes, the informal American scheme used primarily in North America sometimes known as APA (American Phonetic Alphabet), and the IPA (International Phonetic Alphabet), promulgated by the International Phonetic Association. The primary difference between these systems is that in certain cases the American scheme uses a regular letter plus a diacritic where IPA tends to use separate special characters. Thus the sound spelled <sh> at the beginning of 'ship' would be transcribed as [š] in the American system, but with the separate letter [ʃ] in IPA. There are relatively few differences between the two systems, and you should become familiar with both systems (actively with one and passively with the other). This text uses APA: the distinctly IPA symbols are given in section 3. In this chapter, we will aim for a general overview of transcription and articulation. The goal is not to have a complete account of of these topics, but rather to mention the important phonetic symbols, so that the student has a working knowledge of basic transcription, as well as an introduction to the articulatory basis for speech sounds which will be referred to in discussing phonological processes.

Angled brackets represents spelling and square brackets, viz. [šɪp] are for phonetic representation. Underlying forms, found in later chapters are placed in slanted brackets, viz. /šip/.

1. Vowels: their symbols and properties

Conventionally, the first division in speech sounds is made between vowels and consonants. Symbols for vowels will be considered first, because there are fewer vowels than consonants. American English has a fairly rich vowel inventory, so we can illustrate most of the vowel symbols with English words.

(1)

symbol	*English equivalent*
i	‘beat’ [biyt]
ɪ	‘bit’ [bɪt]
e	‘bait’ [beyt]
ɛ	‘bet’ [bɛt]
æ	‘bat’ [bæt]
a	‘cot’ [kat]
ɔ	‘caught’ [kɔt]
o	‘coat’ [kowt]
ʊ	‘could’ [kʊd]
u	‘cooed’ [kuwd]
ʌ	‘cud’ [kʌd]
ə	(unstressed vowel in) ‘array’ [ərḗy]

The glides *y* and *w* in the transcription of tense vowels in English reflects the phonetic diphthongal quality of these vowels, which is especially evident when one compares the pronunciation of English “say” and Spanish “se”. There are many different ways of transcribing that vowel, e.g. [se], [se:], [sei], [seɪ], [se^{I}] and [sey]. Transcriptions like [se] or [se:] are much broader, that is, reveal less of the phonetic details of English because they suppress the information that they are **diphthongs** — which can be predicted by a rule — whereas [sei], [seɪ], [se^{I}] and [sey] report this phonetic property. There is little scientific basis for picking a specific one of these latter four transcriptions as a representation of how the word is pronounced, and you are likely to encounter all of them in one source or another.

A diphthong is a sequence of vowel-like elements — vowels and glides — in one syllable

Some dialects of English make is no distinction in the pronunciation of the words ‘cot’ and ‘caught’; even among speakers who distinguish the pronunciation of ‘cot’ and ‘caught’, the precise pronunciation of the two vowels differs considerably. An important point developed in this book is that transcriptional symbols are approximations representing a range of similar values, and that symbols do not always have absolute universal phonetic values.

Tongue and lip position in vowels. Values of phonetic symbols are defined in terms of a variety of primarily articulatorily-defined phonetic dimensions as in (2).

(2)

	Front unrounded	Central unrounded	Back rounded	
tense	i		u	high
lax	ɪ		ʊ	
tense	e	ə	o	
lax	ɛ	ʌ	ɔ	mid
	æ	a		low

The three most important properties for defining vowels are **height**, **backness**, and **roundness**. The height of a vowel refers to the fact that the tongue is

higher when producing the vowel [i] than when producing [e] (which is higher than that used for [æ]), and the same holds for the relation between [u], [o] and [a].

Figure 11: Tongue position of vowels

Three primary heights are generally recognized, namely *high*, *mid* and *low*, with secondary distinctions introduced either under the name *tense* ~ *lax* or *close* ~ *open* to distinguish vowel pairs such as [i] ("seed") vs. [ɪ] ("Sid"), [e] ("late") vs. [ɛ] ("let") or [u] ("food") vs. [ʊ] ("foot"), where [ieu] are tense (close) and [ɪɛʊ] are lax (open). Tense vowels are higher and often less centralized compared to their lax counterparts.

Independent of height, vowels can differ in their relative frontness of the tongue. The vowel [i] is produced with a relatively front tongue position, whereas [u] is produced with a relatively back tongue position. In addition, [u] is produced with rounding of the lips: it is common but by no means universal for back vowels to also be produced with lip rounding. Three phonetic degrees of horizontal tongue positioning are generally recognized: *front, central* and *back*. Finally, any vowel can be pronounced with protrusion (rounding) of the lips, and thus [o], [u] are rounded vowels whereas [i], [æ] are non-rounded vowels.

With these independently controllable phonetic parameters — five degrees of height, three degrees of fronting, and rounding versus non-rounding — one predicts the possibility of up to thirty vowels, which is many more vowels than are found in English. Many of these vowels are lacking in English, but can be found in other languages. Here are a few examples:

(3)	ü	high front round vowel (found in German, French, Turkish)
	ʊ̈	lax high front round vowel (found in Icelandic)
	ö	mid front round vowel (found in German, French, Turkish)
	ɔ̈	lax mid front round vowel (found in Swiss German)
	œ	low front round vowel (found in French)
	ɨ, ɯ	central (or back) unrounded vowel (found in Turkish, Russian)

All of these vowels can be characterized in terms of the three basic vowel properties of height, backness and rounding. A more complete listing of vowel symbols is given below. It should be borne in mind that the exact phonetic defini-

tions of certain symbols, especially those for low vowels, central vowels, and back unrounded vowels, can vary somewhat in actual usage. Therefore, the symbol <a> might be used to denote a back vowel rather than a central vowel in many published sources; it may also be used for a low front vowel, one which is phonetically lower than [æ].

(4)

	Front unrounded	Central unrounded	Back unrounded	
tense	i	ɨ	ɯ	high
lax	ɪ			
tense	e	ə	ɤ	
lax	ɛ	ʌ		mid
	æ	a,ɐ	ɑ	low

	Front rounded	Central rounded	Back rounded	
tense	ü	ʉ	u	high
lax	ʊ̈		ʊ	
tense	ö	ɵ	o	
lax	ɔ̈		ɔ	mid
	œ		ɒ	low

While this yields a fairly symmetrical system of symbols and articulatory classifications, there are gaps such as the lack of tense/lax distinctions among low vowels or central vowels except for the [ʌ] ~ [ə] distinction.

These properties of tongue and lip position are the ones most commonly exploited for making vowels, but there are a number of other phonetic properties that play a role in defining vowels, and we turn to those properties next.

Nasalization. Typical vowels are produced with air flowing from the lungs though the mouth, but any vowel can be produced with **nasalization**, where air flows through the nose as well as through the mouth, by lowering the velum. Nasalized vowels occur in French, Portuguese, Hindi and a number of other languages. Rather than representing each nasalized vowel with its own symbol, the property of nasalization is symbolized with a tilde diacritic (˜) placed over the vowel, so the phonetic transcription of French *bon* would be [bɔ̃].

Length. Vowels (as well as consonants) may also be either long or short, that is, produced with relatively greater versus lesser duration, and length can be represented with a colon (:), a macron (ˉ), a raised dot (·) or a pair of points which resemble a colon (:) placed after the appropriate symbol. Thus a long version of the vowel [a] may be symbolised as [a:], [ā], [a·] or [a:]. Equally common is the practice of doubling the vowel or consonant symbol, so long [a] could be represented

as [aa]. Examples of languages which systematically exploit the difference between long and short vowels include Japanese ([go] '5', [goo] 'issue') and the Bantu language Kikerewe ([ihuna] 'owl' versus [ihuuna] 'hut'). Languages with long and short consonants include Japanese ([ita] 'was' versus [itta] 'went') and Saami ([miella] 'intention (nominative)' versus [miela] 'intention (accusative)').

Stress. The marking of **stress** generally encompasses the distinction between primary stress, notated with an acute accent (´), and secondary stress, marked with a grave accent (`); alternatively, raised and lowered ticks (ˈ, ˌ) may be placed before the consonants of a stressed syllable. The first syllable of the English word "telegraphic" has a secondary stress and the third syllable has the primary stress: thus the word could be transcribed either as [tɛ̀ləgrǽfɪk] or as [ˌtɛləˈgræfɪk]. It is notoriously difficult to give any simple definition of the acoustics or articulation of stress, and indeed the phonetic realization of stress seems to vary considerably across languages, being expressed in terms of amplitude, pitch, duration, vowel quality, as well as a host of other properties. Typically, though, stressed syllables have higher pitch and greater duration and amplitude.

Tone. Tone differences, as found in many Asian, American and African languages and in addition a few European languages such as Norwegian and Swedish, are also typically transcribed with accent marks. The articulatory basis for producing tone is the rate of vocal fold vibration, which we perceive in terms of *pitch*, so that the vocal folds might vibrate at the rate of 120 cycles per second (120 Hertz, abbreviated Hz) for the production of a low-pitched vowel and at the rate of 170 Hz for the production of a high-pitched vowel. The actual frequency of vibration of a given tone varies from language to language, and also varies from speaker to speaker (depending on age, size, and gender inter alia), and even varies within a speaker depending on mood, emphasis and so on. Thus tones do not represent specific frequency values, but are defined relative to the given pitch range being used. A high tone is relatively high within the range that a speaker is using, and if the physical range is raised or lowered, the actual pitch of a high tone is raised or lowered. The traditions for marking tone are rather varied. Accents are generally used to mark tones, and the following examples illustrate the most common usages. As many as five distinct levels are distinguished, arranged in (5) from highest to lowest in pitch.

(5)	a̋	superhigh toned [a]
	á	high toned [a]
	ā or a̍	mid toned [a]
	à	low toned [a]
	ȁ	superlow toned [a]

The characteristic property of a contour toned vowel is that pitch changes during the vowel, and we can characterize the contour in terms of the tonal values at the beginning and ending points. The diacritic for rising tone is a 'hacek', as in [ǎ], which combines grave accent (as in [à]) followed by acute accent (as in [á]), reflecting the fact that a rising tone begins low and ends high. Falling tone is analogously symbolized with a circumflex, as in [â] since it starts high (acute accent) and ends low (grave accent). Many other combinations are possible, for example a mid-to-high rising tone which combines the accents for mid and high as in [ā´]: you can see that rather than defining a large number of special symbols to indicate the 20 possible contour tones, it is simpler to define symbols for specific levels and describe contours as movement between levels. Another convention for marking tones is to write a superscripted number refering to the pitch level, e.g. ta^{3}, and combinations of numbers to mark contours e.g. ta^{31}. Traditions for languages in different parts of the world, such as Africa vs. Asia or Mexico differ as to whether 1 refers to the highest or lowest pitch level.

Another pitch property of importance to phonological analysis is *downstep* and *upstep*, which are the systematic lowering and raising of the overall pitch space for lexical and grammatical purposes. When a downstep occurs (symbolized by a raised exclamation mark as in (6)), it indicates that all subsequent tones are produced with the upper and lower values of the pitch range decreased. An example comes from Akan, a language of Ghana. Phonologically, each vowel after the first syllable [mè] has a high tone. However, as indicated by the downstep marker, the actual pitch level of a high tone is lower on the third vowel than it is on the second vowel; the pitch of the fifth high-toned vowel is lower than that of the sixth, and so on — in principle, this process can continue infinitely, the only limit being the speaker's ability to actually produce lower pitches.

(6) mè kó˖fí ɛ́˖dɔ́ á˖bóá dá˖déɛ́ ḿ˖pá

[¯ – – – – – – – – – – – – –] "My Kofi's love's pet iron bed"

Analogous to downstep, upstep involves raising the pitch range. Upstep, symbolised with a raised inverted exclamation mark, is rare in comparison to downstep, but is found in Krachi, another language of Ghana: the upstep appears between the third and fourth vowels.

(7) àĺı kɔ́˵tɔ́˵ná "our mat"

[_ – – ¯ –]

Downstep and upstep may also be symbolized with downward and upward arrows, viz. [á˖pá] = [á↓pá], [á˵pá] = [á↑pá].

Phonation type. A number of languages such as Ju /'hoansi, Dinka, Hmong and Mazateco employ distinctive patterns of vocal fold vibration or **phonation** in the production of certain vowels. One such phonation, known as creaky voicing or laryngealization, is produced by closing the vocal folds abruptly and gives vowels a particularly 'sharp' sound, which is notated by placing a tilde beneath the vowel. The other type of phonation, know as breathy voice, is produced by more gradual and even incomplete closure of the vocal folds giving vowels a 'soft' quality, and is marked with two dots below the vowel.

(8) ạ̰ creaky [a]
ạ̤ breathy [a]

These modes of phonation are probably familiar to most people (but the labels assigned to these phonations are unfamiliar), since some individuals systematically speak with a creaky quality to their voice (for example, the actor Edward G. Robinson), or with a breathy quality (Marilyn Monroe). What is special about these phonations in languages such as Ju /'hoansi is that they can be used as a meaningful property of specific words realised on single segments, not just as general voice quality properties of all sounds coming from a particular speaker.

Glides. Standing between consonants and vowels in terms of their phonological function and phonetic properties are the glides, also known as semi-vowels. The typical glides are [y] and [w] as in English "yes", "wet", termed "palatal" and "labial" or "labio-velar". These glides are very similar to the high vowels [i], [u], but are shorter and have a greater degree of constriction than the corresponding vowels. It is often very difficult to distinguish glides and vowels based solely on what they sound like, and one often has to consideration the rules of the language in order to decide whether to transcribe e.g. [kau] or [kaw], [tua] or [twa]. In addition, some languages such as French, Chinese and Kotoko have a "labio-palatal" glide, with the tongue position of [y] and the lip position of [w], transcribed as [ẅ]: an example from French is *huit* "eight" which is transcribed as [ẅit]. Like vowels, glide may also be nasalized, breathy, or creaky.

2. Consonants: their symbols and properties

There are many more consonants found in languages than there are vowels. English only has a fraction of the full range of possible consonants, so illustration of many of these symbols involves more extensive consideration of languages other than English. Most English dialects systematically use the following consonants:

(9)	p	‘**p**ig’	b	‘**b**ig’
	m	‘**m**ug’	f	‘**f**og’
	v	‘**v**armint’	θ	‘**th**ing’
	ð	‘**th**is’	t	‘**t**op’
	s	‘**s**op’	d	‘**d**og’
	n	‘**n**og’	č	‘**ch**uck’
	š	‘**sh**uck’	ǰ	‘**j**ug’
	ž	‘mea**s**ure’	k	‘**c**ot’
	g	‘**g**ot’	ŋ	‘ha**ng**’
	h	‘**h**orse’		

There are a few additional phonetic segments found in English which, because they only arise due to general rules of the type to be discussed in the next chapter, are not immediately obvious:

(10) φ voiceless bilabial fricative; variant of *p* found in words like ‘ras**p**s’ in casual speech.

x variant of *k* found in words like ‘mas**k**s’ in casual speech; also found in German, Russian, Greek, Scots (English).

ɱ labio-dental nasal; variant of *m* found before [f] and [v] as in ‘co**m**fort’.

t̪ dental ‘t’. Found in English before [θ]: the word ‘width’ is actually pronounced [wɪt̪θ]. Also how ‘t’ is pronounced in French.

n̪ dental ‘n’; found in English before [θ] as in ‘pa**n**ther’.

ʔ glottal stop; found in most dialects of American English (except in certain parts of the American south, such as Texas) as the pronunciation of ‘t’ before syllable ‘n’, i.e. ‘bu**tt**on’. Also stereotypical of British ‘Cockney’ pronunciation ‘bo**tt**le’, ‘cou**ld**a’.

Some other consonants found in European languages, for instance, are the following.

(11) p^f, t^s voiceless labiodental and alveolar affricates found in German (<Pfanne> [p^fanə]‘pan’, <Zeit> [t^sait] ‘time’)

β voiced bilabial fricative, found phonetically in Spanish (<huevo> [weβo] ‘egg’)

γ voiced velar fricative, found in Modern Greek ([aγapo] ‘love’) and Spanish (<fuego> [fweγo] ‘fire’)

Many consonants are only encountered in typically unfamiliar languages, such as retroflex consonants (*ʈ* etc.) found in Hindi, Tamil and Ekoti, or uvulars and pharyngeals such as *q*, *χ*, *ħ* found in Arabic.

Consonant symbols are traditionally given in tabular form, treating the place of articulation where the major constriction occurs as one axis, and treating properties such as voicing, being a continuant, or nasality as the other axis. Eleven places of articulation for consonants are usually recognized: bilabial, labiodental, dental, alveolar, alveopalatal, retroflex, palatal, velar, uvular, pharyngeal and laryngeal, an arrangement which proceeds from the furthest forward to furthest back points of the vocal tract: see fig. 9 of Chapter 1 for anatomical landmarks. Manner of articulation refers to the way in which a consonant at a certain place of articulation is produced, indicating how airflow is controlled: the standard manners include stops, fricatives, nasals and affricates. A further property typically represented in these charts is whether the sound is voiced or voiceless. The following table of consonants illustrates some of the consonants found in various languages, organized along those lines.[1]

(12) **Consonant symbols**

	vcls. stop	vcls affric.	vcls. fric.	vcd. stop	vcd. affric.	vcd. fric.	nasal
bilabial	p	(p$^{\varphi}$)	φ	b	(b$^{\beta}$)	β	m
labiodental		p^{f}	f		b^{v}	v	ɱ
dental	t̪	t$^{\theta}$	θ	d̪	d^{ð}	ð	n̪
alveolar	t	t^{s}	s	d	d^{z}	z	n
alveopalatal		č, t^{š}	š		ǰ, d^{ž}	ž	ñ
retroflex	ṭ	ṭ^{ṣ}	ṣ	ḍ	ḍ^{ẓ}	ẓ	ṇ
palatal	c	(c^{ç})	ç	ɟ	(ɟ^{ʝ})	ʝ	ñ
velar	k	k^{x}	x	g	g^{ɣ}	ɣ	ŋ
uvular	q	q^{χ}	χ	ɢ	ɢ^{ʁ}, ɢ^{ʁ}	ɣ̣, ʁ	ŋ̣, ɴ
pharyngeal			ħ			ʕ	
laryngeal~ glottal	ʔ		h	ɦ			

2.1. Place of articulation

The place of articulation of consonants is divided into primary place of articulation — something that every consonant has — and secondary place of articulation — something that some consonants may add to a primary place of articulation. We begin with primary place. Proceeding from the furthest-forward articulation (the top row of (12)) to the furthest-back articulation (the bottom row of (12)), the bilabial consonants such as *m* involve a constriction involving both lips. This closure of the lips is not just a property of *m*, it is a defining characteristic of the

[1] Exception for *č, ǰ*, affricates are symbolized by combining the relevant stop and fricative component. Some theoretically expected affricates have not been observed and are placed in parentheses.

whole bilabial row *p, p*$^{\varphi}$*, φ, b, b*$^{\beta}$*, β* and *m*. A labio-dental constriction as found in *f* is formed with a constriction between the lower lip and the upper teeth.

Lingual consonants. The tip or blade of the tongue is the active (moveable) articulator in the production of many consonants, including dental, alveolar, alveopalatal, retroflex and palatal consonants. These consonants form a constriction involving the tongue and an appropriate place on the teeth, or hard or soft palate. The contact is with the teeth in the case of dentals, on the hard palate behind the teeth in the case of alveolars, behind the alveolar ridge in the case of alveopalatals and retroflex consonants, and with the blade of the tongue at the boundary between the hard and soft palate in the case of palatals. In many traditional organisations of segments, retroflex consonants are classified as a separate place of articulation from alveolars and alveopalatals. This traditional concept of "place of articulation" combines properties of both active (moveable) articulators and a passive articulator — the target towards which an active articulator moves. What unifies the various kinds of retroflex consonants across languages is not the specific location of the constriction on the hard palate, but rather the manner in which just the tongue tip approaches the palate.

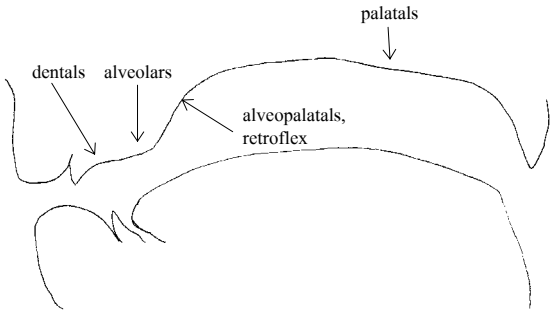


Figure 12: Lingual places of articulation

The terminology used for "palatal" sounds may be particularly confusing. Alveopalatals (sometimes termed "palatoalveolars") are exemplified by the English consonants [š ž č ǰ] ("sheep", "measure", "watch", "judge", and ("true") palatals are found in Norwegian *kjøpe* [çö:pe] "buy" and German *ich* [iç] "I". The term "palatalized" refers to a secondary articulation (discussed below), but in some linguistic traditions such consonants may also be called "palatals". In addition, alveopalatals may be palatalised or not: the Russian fricatives <ж ш> [š ž] are non-palatalized whereas the affricate <ч> [č^{y}] is a palatalised alveopalatal.

"Back" consonants. The body of the tongue can also be positioned in a number of places in the back of the vocal tract to form a constriction, so if the tongue is re-

tracted and raised a velar consonant such as *k* ("cool") is formed; if the tongue is retracted but not raised so that it approaches the uvula, a uvular such as *q* is formed, and if the tongue is retracted and lowered toward the pharynx, a pharyngeal such as *ʕ* is formed. Finally, a consonant can be formed with no constriction above the glottis, when the constriction is made with the vocal folds as in the case of the laryngeal consonants *h, ʔ*.

Secondary articulations. Consonants may have more than one point of constriction: generally, one of these constrictions is the major (most radical) constriction and the other constrictions are less radical — more vowel-like in nature. The most common of these secondary constrictions are given in (13). Secondary articulations are notated by combining the appropriate symbol for the primary place with the symbol representing a kind of glide at the secondary place of articulation.

(13)

		secondary articulation	*example language*
p	t	(plain)	English
p^{y}	t^{y}	palatalized	Russian
p^{w}	t^{w}	rounded	Lushootseed
$p^{ɯ}$,$p^{ɣ}$,p^{x},$p^{\sim}$	$t^{ɯ}$,$t^{ɣ}$,t^{x},$t^{\sim}$	velarized	Marshallese
$p^{ʕ}$	$t^{ʕ}$	pharyngealized	Arabic
$p^{ẅ}$	$t^{ẅ}$	rounded and fronted	Baule

Plain consonants are those produced with only a single, narrow constriction. Palatalized consonants are formed by combining the basic constriction of the consonant with a less radical vowel-like constriction of the kind that is found in the glide *y* or the vowel *i*; secondarily articulated consonants sound essentially like combinations of consonant plus a glide *y*, *w*. Rounded consonants analogously involve a protrusion of the lips (as do round vowels and the glide *w*). Velarized consonants are produced by combining the narrower primary articulation of a consonant with a raised, retracted tongue position which is similar to the back unrounded vowel [ɯ] or the velar fricative [ɣ], and pharyngealized consonants combine a consonantal constriction with a retracted and lowered tongue position, appropriate for a pharyngeal consonant such as [ʕ]. Rounding of the lips and fronting of the tongue can be combined simultaneously in a secondary articulation, e.g. [$t^{ẅ}$].

Consonants formed with two major constrictions. In a number of languages of Africa (Yoruba, Nupe, Konni, Kuku, and others), as well as some languages of New Guinea (Amele), there are consonants typically transcribed as *kp*, *gb*, *ŋm*, which are phonologically single consonants produced with two (virtually) simultaneous complete constrictions, one at the lips and the other formed by raising the body of the tongue to the soft palate, as in the production of a velar. Occasionally, to make clear that this is a single consonant, a 'tie' character is written over the

two components, viz. *k͡p, g͡b*. This would be especially necessary in a language like Eggon, which phonetically distinguishes the consonant cluster *k+p, g+b* from single consonants with simultaneous labial and velar constrictions, for example [k͡pu] "die" with a single consonant at the beginning versus [kpu] "kneel" with a cluster; [g͡bu] "arrive" with a labiovelar, and [gba] "divide" with a cluster of a velar followed by a labial.

If consonants can be formed by simultaneously combining both complete labial and velar constrictions, one would reasonably expect there to exist other such consonants with lingual and velar constrictions, or lingual and labial constrictions. In fact, **clicks** such as lateral [‖], alveolar [!], palatoalveolar [≠] or dental [|] which are found in Khoisan language such as !Xõo and Khoekhoe or southern Bantu languages such as Zulu and Xhosa are exactly such lingual-velar consonants. These consonants are formed by raising the back of the tongue to form a constriction at the velar place of articulation, and raising the tip or blade of the tongue to make an appropriate constriction on the palate. The middle of the tongue is lowered, creating a vacuum. When the lingual constriction is released, a very loud noise results, which is the typical sound of a click. Finally, lingual-labial consonants i.e. *t͡p,* which involve simultaneous complete constrictions with the tongue and lips are found in the New Guinean language Yeletnye.

2.2. Manner of articulation

Stops, fricatives and affricates. Largely independent of the place where a consonant's constriction is formed, the manner in which the constriction is formed can be manipulated in various ways. If a constriction is formed which completely blocks the flow of air, the resulting sound, such as *t*, is called a **stop**. A consonant can also be produced by forming a narrow constriction which still allows air to pass through the vocal tract resulting in noise at the constriction, and such consonants, for example *s* and *v*, are called **fricatives**. A combination of complete constriction followed by a period of partial constriction is termed an **affricate**, as in *č*. From a phonetic perspective, such consonants can generally be thought of as a sequence of a stop plus a fricative at the same place of articulation (a *homorganic* sequence). From a phonological perspective, they function as single stop consonants, and are considered to be a particular kind of stop consonant, one with an affricated release. Even from a phonetic perspective, the characterization of affricates as sequence of stop plus fricative is not completely adequate, since there are cases where there is a phonetic difference between stop plus fricative, versus affricate. The most well-known case of this type is Polish, which contrasts the affricate [č] versus the stop-plus-fricative sequence [tš] in the words [čɨ] 'whether' versus [tšɨ] 'three'.

Liquids, glides and approximants. Additionally, languages typically have some kind of **liquid** consonants, a class of consonants involving the blade or tip of the tongue in their production. The typical examples of liquids are [r] and [l]. The symbol [r] is generally used to refer to "trilled r" as found in Italian. The variety of "r" used in American English is, phonetically speaking, a **glide** or **approximant**, which is a segment involving very little constriction in the vocal tract, and would be transcribed as [ɹ]. Some languages also have a type of "r" which is produced by quickly tapping the tongue against the alveolar ridge: this flapped "r" would be transcribed as [ɾ]. English actually has this segment, which is a phonetic variant of /t/ and /d/ in words such as "motto" which is phonetically [mɔɾow]. The flapped variant of /t,d/ is also often transcribed as [ᴅ]. The uvular "r" found in French, German and the Bergen dialect of Norwegian is transcribed as [ʀ].

The concept "approximate", which is not widely used in the phonological literature, is a broader category that includes glides and liquids. The phonetic literature tends not to use the term "glide".

Laterals. Consonants produced with the blade of the tongue may be produced in such a way that air flows over the sides of the teeth, and such consonants are referred to as *laterals*. English *l* is an archetypical example of a lateral; languages can have lateral fricatives such as voiceless [ɬ] (or [ꞎ]) which appears in Welsh, Lushootseed, Zulu and Xhosa, and voiced [ɮ] found in Zulu and Xhosa, affricates such as [λ] (also transcribed [tˡ]) found in nmany languages of the Pacific Northwest, and lateral clicks such as [ǁ].

Nasalization. There are other phonetic properties which relate to the manner in which consonants are produced, apart from the location of the constriction. One such modification, which we have already considered since it is applicable to vowels, is nasalization. Consonants such as [m,n,ñ,ŋ] are the archetypical nasals; however, one can produce other nasal consonants (or, 'nasalized' consonants) by lowering the velum during the production of the consonant. Such nasalized consonants are rare, due to the fact that it is quite difficult to distinguish them from from their oral counterparts, but nasalized versions of fricatives and approximates such as [h], [β], [v], [γ], [r], [l] do exist in the world's languages. Nasalized fricatives are extremely rare, but the fricative [ṽ] is attested in Umbundu (Schadeberg 1982), and voiceless nasal fricatives are found in Coatzospan Mixtec (Gerfen 2001). It is also claimed that various languages have 'prenasalised' consonants, transcribed ^{m}b, ^{n}d, ^{ŋ}g, but it is controversial whether these are truly single segments, and not just clusters of nasal plus consonant, i.e. *mb, nd, ŋg*.

2.3. Laryngeal properties

Different actions of the larynx result in a considerable number of consonantal distinctions. The following examples illustrate the major consonant differences which are due to the action of the larynx.

(14)	p	t	k	unaspirated voiceless
	b	d	g	unaspirated voiced
	p^h	t^h	k^h	aspirated voiceless
	b^h~$b^ɦ$~$b̤^ɦ$	d^h~$d^ɦ$~$d̤^ɦ$	g^h~$g^ɦ$~$g̤^ɦ$	aspirated voiced
	p’	t’	k’	ejective
	ɓ	ɗ	ɠ	implosive

Voiced stops are produced with vibration of the vocal folds during their production, whereas voiceless stops are produced with no such vocal fold vibration. Voiceless aspirated stops differ from voiceless unaspirated stops by the presence, in aspirated stops, of a significant delay between the moment when the constriction for the consonant is released and the moment when voicing begins. Such sounds are typically perceived as having a ‘puff of air’ at their release, due to the high volume of air flow during their production. Voiced aspirated consonants, on the other hand, maintain vocal fold vibration, but also are produced with spread vocal folds, resulting in high air flow and a ‘murmured’ quality. Implosives and ejectives are produced by one basic glottal gesture, but they are differentiated in terms of supplementary laryngeal actions. In the case of ejectives, the glottis is first constricted, then the larynx is raised resulting in high pressure in the vocal tract behind the main consonantal constriction; when that constriction is released, a loud high-pitched popping sound results. In the case of implosives, the glottis is also constricted, but is then lowered resulting in a vacuum within the oral cavity. When the constriction is released, a dull, lower-pitched sound results.

A final property of stop consonants, partially related to laryngeal activity, is the property of release. In some languages, stop consonants in certain positions (before other consonants or at the end of a word) are produced without audibly releasing the consonantal constriction. This property of consonants is notated with the symbol [˺]. In American English, voiceless consonants, especially *t*, are often unreleased at the end of the word, and thus ‘hit’ may be realised phonetically as [hɪt˺]. This generally involves cutting off the flow of air at the glottis during or somewhat before the time when the consonant closure is made. When pronounced with release, as [hɪt], there is a brief burst of noise as the consonant constriction is released and air begins to flow again, which sounds like aspiration.

2.4. Syllabicity

A further phonetic property of consonants that may be transcribed is whether the consonant is *syllabic*. There is a phonetic difference between the *n* of American English ‘cotton’ and that of ‘con’: the *n* of ‘cotton’ is syllabic, whereas the *n* of ‘con’ is non-syllabic. A syllabic consonant is indicated by placing a vertical tick under the consonant, so ‘cotton’ is transcribed [kaʔn̩] and ‘con’ is transcribed [kan]. There is no simple definition of ‘syllabic consonant’ versus ‘nonsyllabic consonant’, save that a syllabic consonant forms the peak of a syllable

and a nonsyllabic consonant does not. Given that ‘cotton’ has two syllables, and taking it for the moment to be a principle that every syllable has a peak, then *n* must be the peak of the second syllable in ‘cotton’. The main phonetic correlate of the distinction between syllabic and non-syllabic consonant is duration, where syllabic consonants are generally longer than their nonsyllabic counterparts. Especially in tone languages, syllabic consonants can have distinctive tone, for example Kihehe [ń̩dage] “chase me!”.

Because the concept “syllabic consonant” depends on the notion “syllable”, we also need to consider the syllable itself, and how to indicate it in a transcription. It is generally agreed that in English, the words *spring, sixths* and *Mike* have one syllable, and *osprey, happy* and *atone* have two. The syllable is made up of a contiguous sequence of segments, so the main issue regarding syllables is where the syllable begins and ends. The conventional symbol for marking the beginning and end of a syllable is a period, which can be unambiguously assigned in the monosyllabic words [.sprɪŋ.], [.sɪksθs.] and [.mayk.]. There is also no problem in deciding where the syllable breaks are in [.ə.lǽw.]. However, in dealing with words having certain clusters of consonants or certain stress patterns, the question becomes more complicated. It would be reasonable to transcribe “osprey” either as [.ás.pri.] or [.á.spri.] (whereas *[.ásp.ri.] would almost certainly be wrong for any speaker of English), and research on the organisation of syllables has in fact proposed both [.hǽ.pi.] and [.hǽp.i.] as transcriptions for the word “happy”. Determining syllable boundaries is thus not trivial.

A number of sonorant consonants of English can be syllabic: [baɒl̩] ‘bottle’, [fr̩] ‘fur’, [lɛsn̩] ‘lesson’. There is even a special phonetic symbol for syllabic [r̩] called ‘schwar’, written either as [ɚ] or [ɝ]. Syllabic sonorants also exist in other languages, such as Sanskrit, Serbo-Croatian, and many African languages. Generally, one finds syllabic sonorants only between consonants, or between a consonant and the beginning or end of a word. Thus in English, final [r] is nonsyllabic when it is preceded by a vowel, as in [kar] ‘car’, and syllabic when preceded by a consonant, as in [kapr̩] ‘copper’. One can almost completely predict the difference between syllabic and nonsyllabic sonorant in English from surrounding segments. However, in normal speech American English [təreyn] “terrain” is pronounced as [tr̩eyn] distinct from “train” which is [treyn], and [pəlayt] “polite” is pronounced as [pl̩ayt] which is different from [playt] “plight”. Still, the syllabic consonants can be predicted by a rule in English. In some languages this is not possible: in Serbo-Croatian the word *groze* ‘fear (genitive)’ has a nonsyllabic [r] before a vowel and *gr̩oce* ‘little throat; larynx’ has syllabic [r] in the same context. In Swahili, the word [mbuni] ‘ostrich’ has a nonsyllabic [m], and [m̩buni] ‘coffee plant’ has a syllabic [m] in the same position.

2.5. Symmetry in consonants

There would be gaps in what might otherwise be a symmetrical universal table of consonants, were we to list all of the consonants found in human languages. In some instances, the gap reflects physiological impossibility, such as the fact that one cannot produce a nasal pharyngeal, analogous to velar nasal [ŋ] but at a pharyngeal place of articulation. A nasal involves making a complete obstruction at a given point of articulation and also requires air to flow through the velum. In order to make a pharyngeal nasal, it would be necessary to make a complete constriction at the pharynx. But since the pharynx lies below the velum, no air can flow through the nasal passages if the pharynx is totally constricted. However a nasalized pharyngeal continuant, i.e. the consonant [ʕ̃] produced with simultaneous nasal airflow, would not be a physical impossibility, since that consonant does not require complete constriction of the pharynx. In other cases, the gap indicates that no such sound has been found, but there is no immutable physical reason for such a sound not to exist. Thus bilabial affricates do not seem to be attested, nor do plain non-affricated alveopalatal stops — nor do nasalised pharyngeal fricatives. Similarly, while pharyngealised consonants exist, and rounded consonants exist, there are apparently no cases of consonants which are both rounded and pharyngealized, though such segments are not logically impossible. These lacunae may be an indication of a deeper constraint on sound systems; however, it is also possible that these segments do exist in some language which has not been studied yet, since there are many languages in the world which remain uninvestigated.

This does not mean that it is impossible to lower the velum and make a complete pharyngeal constriction at the same time; it means that the air will not flow through the nose, which is a defining property of a nasal consonant, so you could not tell from the sound itself

3. IPA Symbols

The main difference between the preceding system of transcription and the International Phonetic Alphabet (IPA) lies in differences in the symbols used to transcribe vowels. The IPA system for transcribing vowels can be described in terms of the following chart (when vowels are presented in pairs, the first vowel in the pair is unrounded and the second is rounded).

IPA requires close adherence to the graphic design of letters. The IPA symbol for a voiced velar stop is specifically [ɡ] not [g], and the voiced velar fricative is [ɣ] not [γ]. Such fine distinctions in letter shape are irrrelevant in APA tradition.

(15)

	Front		Central		Back	
close	i y		ɨ ʉ		ɯ u	
	ɪ ʏ				ʊ	
close-mid	e ø		ɘ ɵ		ɤ o	
			ɞ			
open-mid	ɛ œ		ɜ ɞ		ʌ ɔ	
	æ		ɐ			
open	a ɶ				ɑ ɒ	

The most important differences between the vowels of the two systems are the following.

(16)

IPA	**APA**	
ø	ö	mid front rounded vowel
œ	œ or ɔ̈	open-mid front rounded vowel (in APA, œ tends to imply a low vowel whereas ɔ̈ represents a lax mid vowel)
ʏ	ʊ̈ or ʏ	lax front rounded vowel
y	ü	front round vowel

In the American tradition, fewer vowel distinctions are generally made, so where IPA treats the members of the following sets as different vowels, APA usage tends to treat these as notational variants of a single vowel. If a distinction needs to be made in some language between nonback unrounded vowels or low vowels, the appropriate IPA symbol will be called upon. APA usage tends to treat [ɯ], [ɨ] and [i] as graphic variants, whereas in IPA they have distinct interpretations.

(17)
ɯ = high back unrounded
ɨ = high central unrounded
ï = high centralized unrounded (between i and ɨ)

Where IPA systematically distinguishes the use of the symbols [æ a ɐ ɑ ɒ], APA usage typically only distinguishes front [æ] and non-front [a].

(18)
æ = not fully open front unrounded
a = low front unrounded
ɐ = not fully open central unrounded
ɑ = low back unrounded
ɒ = low back rounded vowel
(usually all of these are represented as [a] in American usage except for [æ] which represents front low unrounded vowels)

Another more significant difference between the two systems is the difference in terminology for classifying vowels: note that a three-way division into high, mid and low vowels is assumed in the American system, with subdivisions into tense and lax sets, whereas in the IPA, a basic four-way division into close, close-mid, open-mid and open vowels is adopted, where the distinction between close-mid [e] and open-mid [ɛ] is treated as being on a par with the distinction between high [i] and close-mid [e]. High lax vowels are not treated as having a distinct descriptive category, but are treated as being variants within the category of high vowels.

IPA consonant symbols. The following IPA symbols, which are the most important differences between IPA and APA symbols for consonants, should be noted:

(19)	**IPA**	**APA**	
	j	y	palatal glide
	ɥ	ẅ	front rounded glide
	dʒ	ǰ	voiced alveopalatal affricate; <j> is also used
	tʃ	č	voiceless alveopalatal affricate
	ʃ	š	voiceless alveopalatal fricative
	ʒ	ž	voiced alveopalatal fricative
	ɲ	ñ	palatal nasal
	ʂ,ʐ,ɽ,ɭ,ɳ,ɖ,ʈ	ṣ,ẓ,ṛ,ḷ,ṇ,ḍ,ṭ	retroflex s,z,r,l,n,d,t,
	ɾ	ɾ,D	voiced alveolar flap
	ɬ	ɬ,ɬ	voiceless lateral fricative
	ɫ	ɫ,ɬ	velarized l
	c	k^y	voiceless palatal stop
	ç	x^y	voiceless palatal fricative
	dl	λ	voiced lateral affricate
	tl	ƛ	voiceless lateral affricate

This represents the current IPA standard. The IPA has developed over a period of more than a hundred years, and has been subject to numerous revisions. For example in the 1900 version of the IPA, the symbols <ü ï ö ë ɔ̈ ä > indicated central vowels, as opposed to their contemporary counterparts <ʉ ɨ ɵ ɘ ɞ ɐ> (the diacritic [¨] is still used to represent a vowel variant that is closer to the center). The letters [ꝼ] and [ꝿ] were used for the voiceless and voiced bilabial fricatives, in contrast to contemporary [φ] and [β] (or [ɸ] and [β], using the officially sanctioned letter shapes). In the 1914 version, the fricative trill (found in Czech) was transcribed as [ř], in 1947 this was replaced with [ɾ], and in contemporary useage, [r̝] is used. The high lax vowels have been transcribed with the symbols <ꞁ, ꞁ> and <ꞅ, ꞅ, ꞅ> in the history of the IPA. In reading older works with phonetic transcriptions, the student may thus encounter unfamiliar symbols or unfamiliar uses of familiar symbols. The best solution to uncertainty regarding symbols is to consult a reference source such as Pullum & Ladusaw 1986.

4. Illustrations with English transcription

To further illustrate these symbols, we consider the transcription of some words of English, using a broad phonetic transcription, that is, one which does not include a lot of predictable phonetic detail — the issue of predictable features of speech will be taken up in more detail in subsequent chapters. Consider first the transcription of the words [kʌt] ‘cut’, [siys] ‘cease’ and [sɪk] ‘sick’. These examples show that phonetic [s] may be spelled in a number of ways, and that the letter <c> in spelling may have a number of phonetic realizations. The example [baks]

‘box’ further makes the point that one has to be careful of not inadvertently importing English orthography into phonetic transcriptions. A transcription such as [bax] might be appropriate for the name of the composer *Bach* (since many people do pronounce the name with a velar fricative, as it is pronounced in German), but otherwise (barring careful transcriptions of casual speech where *k* is actually pronounced as the fricative [x] in some contexts), [x] does not occur in (standard American) English — it would be appropriate for transcribing Scots *Loch* [lɔx].

Examples like [sɪŋ] ‘sing’, [sɪŋgyəl̩r] ‘singular’, [ʌngluwd] ‘unglued’, [sɪŋk] ‘sink’ and [dɪŋiy] ‘dinghy’ show that <ng> may represent a single segment [ŋ] or a sequence [ŋg] or [ng], and that [ŋ] need not be spelled <ng>. In the word [fənɛɒɪk] ‘phonetic’, there may be some temptation to transcribe the word with the full vowel [o] in the first syllable. This is (almost always) a spelling pronunciation — the first unstressed vowel is pronounced as schwa ([ə]) in American English.

The vowel [e] in words such as ‘same’ in English is noticeably different from the pronunciation of [e] in French, Spanish, Italian or German. In English, the ‘pure’ vowels [e], [o], [i] and [u] do not exist by themselves, and are always combined with a glide of similar phonetic quality, forming what is referred to as a *diphthong*. Thus the transcriptions [seym] ‘same’, [town] ‘tone’, [tiym] ‘team’ and [tuwn] ‘tune’ are more phonetically accurate characterizations of the pronunciations of these words. These diphthongs are sometimes also written as [ei], [ou] or [eɪ], [oʊ]. The glide element is also frequently omitted, since it can be predicted by a rule, and thus these words might also be transcribed as [sem], [ton], [tim] and [tun]. However, in [tæwn] (or [tawn], depending on which dialect you speak) ‘town’, [taym] ‘time’ and [toyl] ‘toil’, the glide element of the diphthong is not predictable by rule and must be included in any transcription.

In the words [riyɒɪŋ] ‘reading’ and [skeyɒɪŋ] ‘skating’, both orthographic <t> and <d> are pronounced the same, with the flap [ɒ]. Some dialects of English maintain a phonetic difference between ‘riding’ and ‘writing’, either via a difference in vowel length ([ra:yɒɪŋ] ‘riding’ vs. [rayɒɪŋ] ‘writing’) and/or by a vowel quality difference ([rʌyɒɪŋ] ‘riding’ vs. [rayɒɪŋ] ‘writing’).

The word [hr̩t] ‘hurt’ has a ‘vowel’ — a syllable peak — which is essentially equivalent to the consonant [r]. Sonorant consonants can function as vowels, thus this ‘vowel’ is referred to as ‘syllabic r’, as indicated by a tick under the consonant. The IPA provides a separate symbol for this particular sound: [ɚ]. Similarly, English has syllabic [l̩] as in [pæɒl̩] ‘paddle’, syllabic [n̩] as in [bʌʔn̩] ‘button’ and syllabic [m̩] as in [skɪzm̩] ‘schism’ (which have no separate IPA symbols). Sometimes the syllabic sonorants are transcribed as the combination of schwa plus a consonant, as in [hərt], [pædəl], [bʌʔən] and [skɪzəm]. It is possible that there are some dialects of English where these words are actually pronounced with a real schwa followed by a sonorant, but in most dialects of American English, they are not pronounced in this way (this is particularly clear is you compare the pronunciation of such English words with that of other languages which do have clear phonetic [ən], [ər] sequences). In addition, as we will discover when we

discuss the rule for glottal stop in English, the presence of glottal stop in [bʌʔn̩] can only be explained if there is no schwa before the sonorant.

Summary

Because phonology views speech sounds symbolically, knowledge of the system of symbols for representing speech is a prerequisite to doing a phonological analysis. It is also vital to know the phonetic parameters for describing the sounds of human languages which have been presented here. The main characteristics of vowels involve fronting of the tongue (*front, central* and *back*), *rounding*, and vowel height (*high*, *mid* and *low*, with *tense* and *lax* variants of high and mid vowels). Other properties of vowels include stress, tone (including *downstep* and *upstep*) and the phonation types creaky and breathy voice. Primary consonantal places of articulation include *bilabial, labiodental, dental, alveolar, alveopalatal, retroflex, palatal, velar, uvular, pharyngeal* and *laryngeal*. These may be supplemented by vowel-like secondary articulations including palatalization, velarization, pharyngealization and rounding. Consonants may be produced with a number of constriction and release types, and may be stops, fricatives or nasals, and stop consonants may be unreleased or released, the latter type allowing plain versus affricate release. Differences in the laryngeal component for consonants includes voicing and aspiration, and the distinction between ejectives and implosives. Vowels and consonants may also exploit differences in nasalization and length.

Appendix 1: Phonetic Symbols (APA)

Vowels

	Front unrounded	Central unrounded	Back unrounded	
tense	i	ɨ	ɯ	high
lax	ɪ			
tense	e	ə	ɤ	
lax	ɛ	ʌ		mid
	æ	a,ɐ	ɑ	low

	Front rounded	Central rounded	Back rounded	
tense	ü	ʉ	u	high
lax	ʊ̈		ʊ	
tense	ö	ɵ	o	
lax	ɔ̈		ɔ	mid
	œ		ɒ	low

Vowel diacritics

ã	nasalized	a:	long		
a̰	creaky	ạ	breathy		
á, ˈa	primary stress	à, ˌa	secondary stress		
a̋	superhigh tone	á	high tone		
ā, a̋	mid tone	à	low tone	ȁ	superlow tone

Consonants

	vcls. stop	vcls affric.	vcls. fric.	vcd. stop	vcd. affric.	vcd. fric.	nasal
bilabial	p	(p^{φ})	φ	b	(b^{β})	β	m
labiodental		p^{f}	f		b^{v}	v	ɱ
dental	t̪	t^{θ}	θ	d̪	$d^{ð}$	ð	n̪
alveolar	t	t^{s}	s	d	d^{z}	z	n
alveopalatal		č	š		ǰ	ž	ñ
retroflex	ṭ	$ṭ^{ʂ}$	ṣ	ḍ	$ḍ^{ʐ}$	ẓ	ṇ
palatal	c	($c^{ç}$)	ç	ɟ	($ɟ^{ʝ}$)	ʝ	ɲ
velar	k	k^{x}	x	g	$g^{ɣ}$	ɣ	ŋ
uvular	q	$q^{χ}$	χ	G	$G^{ɣ}$, $G^{ʁ}$	ɣ̣, ʁ	ŋ̣, N
pharyngeal			ħ			ʕ	
laryngeal	ʔ		h			ɦ	

clicks:	⊙	labial		ǀ	dental
	‖	lateral		!	alveolar
	≠	postalveolar			

implosives: ɓ ɗ ɠ

liquids:	r	trill or tap	ɾ	flap	ɹ	approximant
	ɬ	v'less lateral spirant	ɮ	vd lateral spirant		
	ʎ	palatal lateral	λ	lateral affricate		

glides:	w	labio-velar	y	palatal	ẅ	labio-palatal

Consonant diacritics

p^{y}	palatalized	p^{w}	rounded
$p^{ɯ}$	velarized	$p^{ˤ}$	pharyngealized
$p^{ẅ}$	rounded and fronted	ṭ	retroflex
p^{h}	aspirated voiceless	b^{h}~$b^{ɦ}$	aspirated voiced
p'	ejective	p˺	unreleased
m̩	syllabic	m̥	voiceless

Appendix 2: IPA Symbols

Vowels

	Front		Central		Back	
close	i	y	ɨ	ʉ	ɯ	u
		ɪ ʏ			ʊ	
close-mid	e	ø	ɘ	ɵ	ɤ	o
			ə			
open-mid		ɛ œ	ɜ	ɞ	ʌ	ɔ
		æ		ɐ		
open		a ɶ			ɑ	ɒ

Consonants

	bilab.	labio-dent.	dent.	alveo.	post-alveo.	retr.	palat.	vel.	uvular	phar.	glott.
plosive	p b		t d			ʈ ɖ	c ɟ	k g	q ɢ		ʔ
nasal	m	ɱ	n			ɳ	ɲ	ŋ	ɴ		
trill	ʙ		r						ʀ		
tap, flap			ɾ			ɽ					
fricative	ɸ β	f v	θ ð	s z	ʃ ʒ	ʂ ʐ	ç ʝ	x ɣ	χ ʁ	ħ ʕ	h ɦ
lateral fricative			ɬ	ɮ							
approx.		ʋ	ɹ			ɻ	j	ɰ			
lateral approx.			l			ɭ	ʎ	ʟ			

Exercises

1. Give the phonetic symbols for the following segments:

voiceless alveopalatal affricate
voiceless dental fricative
front lax high unrounded vowel
central mid lax unrounded vowel
voiced velar fricative
front unrounded low vowel
voiced dental fricative
high front rounded tense vowel
front mid lax unrounded vowel
voiced alveolar stop
voiceless laryngeal fricative

2. Give words in English containing the following sounds

(a)	ǰ	(b)	r̪	(c)	ŋ
(d)	š	(e)	θ	(f)	ɛ

3. Transcribe the following words phonetically. If you are a fluent first-language speaker of English, represent your own pronunciation. Otherwise, use the pronunciation of someone else who is a fluent first-language speaker of English.

push	alphabet	collapse
punish	Jurassic	salmonella
diphthong	women	flood

4. From the following pairs of symbols, select the symbol which matches the articulatory description.

ɯ	ɨ	high central unrounded vowel
ã	a̰	creaky [a]
ɢ	g	voiced uvular stop
ɩ	i	lax front high vowel
ʕ	ʔ	glottal stop
œ	ö	low front round vowel
θ	t^{θ}	dental affricate
ž	ʝ	alveopalatal fricative
á	à	low-toned [a]

5. Provide the phonetic symbols for the following sounds.

voiced bilabial fricative
high back unrounded vowel
voiceless uvular ejective stop
front round mid oral tense vowel
voiceless labiodental fricative
rounded voiceless dental stop
low front unrounded vowel
alveolar nasal
voiced retroflex stop
voiced pharyngeal fricative

voiceless alveolar stop

back low unrounded vowel

6. Provide the articulatory description of the following segments (assume the Americanist system of transcription, in case some symbol is ambiguous between the two systems). Example:

θ <u>voiceless interdental fricative</u>

ɔ _____

ə _____

a _____

ɱ _____

d̪ _____

ʊ _____

ü _____

æ _____

œ _____

t^s _____

č _____

ʂ _____

ɟ _____

k^x _____

x _____

ɩ _____

φ _____

b^v _____

g^w _____

g^γ _____

ʔ _____

7. Transcribe the following English words phonetically.

listen	[	]	pleasure	[	]
unique	[	]	who	[	]
attack	[	]	geriatric	[	]
significant	[	]	sample	[	]
contagious	[	]	journal	[	]
resident	[	]	philosophy	[	]
pile	[	]	resign	[	]
attic	[	]	punishment	[	]

Advanced Topics and Readings

Symbols and their sounds. The current standard of the IPA is published by the International Phonetic Association (1999) in *Handbook of the International Phonetic Association*: see Albright 1958 for a historical survey of the IPA. The main reference source for comparative information on the use of phonetic symbols, spanning various traditions and periods, is Pullum & Ladusaw 1986. Pike 1947 is an influential source in establishing Americanist transcription practices.

Ladefoged & Maddieson 1996 gives an extensive discussion of the range of phonetically distinct segments found in languages of the world, and of the phonetic parameters involved, based on the authors' decades of firsthand investigation into the phonetic properties of human language. Along with Ladefoged 2001a,b this will provide the student with an excellent understanding of the range of phonetic variation found in language.

Introductory books in phonetics often explain the production of consonants and vowels, but an explicit articulatory description of how a symbol is produced hardly gives the student much of substance to hang the symbol on. A traditional out-of-print solution to this problem is Smalley 1964 and the accompanying tapes, which give students a recording of the sound that may make the nature of some of these phonetic distinctions more vivid. Digitized examples of various sounds are available on the CD which accompanies Ladefoged 2001a,b, online at http://hctv.humnet.ucla.edu/departments/linguistics/VowelsandConsonants. Other examples of IPA symbols and corresponding sounds may be found at http://web.uvic.ca/ling/ipa/handbook.

Variation in the use of symbols. It might strike the student as peculiar that there are (at least) two systems of transcription — you might think that a single uniform scientific system could be agreed on and used by all linguists. There are a number of reasons why this has not been the case. There is simple tradition: when one has

been brought up to use one system of notation, it is very difficult to suddenly switch to another by decree. Neither system is philosophically more sound or scientifically more accurate than the other, and the choice between systems is based on sociological considerations.

This book uses standard phonetic symbols (following the American practice, which the author has used for years), and exceptions will be explicitly noted when they arise. However, transcriptional ambiguities and inconsistencies abound in the literature, and one must be careful in taking for granted the phonetic interpretation of given data. Published data on languages, especially grammars and other descriptions of language structure, rarely use systems of standard universal systems of phonetic transcription consistently. For example the symbol <c> may be used to represent a palatal stop [k^y], an alveopalatal affricate [č], an alveolar affricate [t^s], an alveopalatal fricative [š], a voiced alveopalatal affricate ([ǰ], in Turkish), a voiced pharyngeal fricative [ʕ] (in Somali), a dental click ([|], in Zulu and Xhosa), not to mention a voiceless velar stop in many European languages and other languages with orthographic traditions influenced by European languages. The symbol [ʈ] will generally represent a retroflex *t*, but in the description of most Semitic languages — which do not have retroflex consonants — it represents a pharyngeal secondary articulation i.e. [$t^ˤ$]; but in some Ethiopian Semitic languages it is used to represent glottalised [t'']. In dealing with original sources (and any linguistic literature based on those sources), it is always wise to check the actual phonetic values of graphemes. The use of a special phonetic symbol such as [ʃ] or [č] is rarely ambiguous, but the use of plain letters such as <y>, <c> and even occasionally <p>[2] may represent the simple practical expedient that it is easier to type 'c' than 'ʕ'. This is why it is important, in looking at language data sources, to carefully check the phonetic descriptions of segments and not just automatically assume that the source is rigorously following a particular linguistic transcription system.

Practical issues have played a major role in the symbols which are used to phonetically represent data. Using "funny" symbols such as [ɯ ɤ ɵ ạ ʕ ɦ ʘ ɓ ʈ ɬ] can significantly increase the cost of typesetting since such symbols cost money to produce and will not be available at all publishing houses. It can also be a considerable nuisance to an author to have to go to various lengths to insert such symbols in a manuscript, hence there is a natural tendency to reduce the number of special symbols used. Practical issues dictated by the need to develop orthographies for unwritten languages quite often lead a descriptive linguist to pick a particular symbol for transcription. Consider the fact that in the spelling of Somali, the consonant [ʕ] is represented with the letter <c> and [ħ] is spelled as <x>. It may be inconvenient to have to remember such a parochial orthographic rule for Somali data, but for speakers of Somali this is a tremendous help, because it means that Somali can be written using standard typewriter symbols. Typewriters can be rigged to include

[2] The letter <p> is used in Yoruba to represent the labiovelar [kp].

these phonetic symbols, but only at great cost. Even when the inclusion of some phonetic symbol is inevitable, the choice of transcriptional system can be influenced by the desire to reduce the number of additional symbols, so in a number of languages spoken in West Africa, the phonetic vowel system [i ɪ e ɛ o ɔ u ʊ] is often transcribed as [i ị e ẹ o ọ u ụ], by the addition of a single diacritic rather than the introduction of four new vowel symbols.

English vowel transcription and the conflicting goals of transcription. Transcription of English vowels can be confusing, since different sources present an inconsistent picture of "correct" transcription of words. In some cases, this is due to different symbol systems — IPA vs. APA — so the difference [fejl] vs. [feyl] for "fail" would be exactly of this nature. Another reason for differences in transcriptions is that the dialect represented may differ in how vowels (to a lesser extent, consonants) are pronounced. This is very clear in the difference between British and American English, and even within these two dialect groups there are major differences in pronunciation so that the vowel of "suit" might be pronounced as [uː], [uw], [ʉ], or [ɪẅ]. The dialect of this author does not distinguish "caught" and "cot", so naturally these words are transcribed the same. In that dialect, "root" is pronounced [rʊt], and "route" and "rout" are pronounced [ræwt], whereas in other dialects "root" and "route" are pronounced as [ruwt] and "rout" is pronounced [rawt].

A third and little-discussed cause of variation in the transcription of English vowels is different implicit goals and assumptions that authors have in creating a transcription. As discussed in the first chapter, information can be added to a transcription to make it a more accurate rendering of a pronunciation: close resemblance to pronunciation is one common goal. Sometimes, though, certain types of information are not only unimportant, but can obscure the cognitive status of certain sounds, by focusing too much on different physical manifestations and deepmphasizing the unity behind the sounds. Chapter 3 discusses a way of removing such information from a transcription, by eliminating properties that can be supplied via automatic rule. Thus another goal of a transcription is to capture and highlight just the *important* information.

No one has ever believed that a totally accurate phonetic transcription is possible (any more than anyone has ever thought that a totally accurate measurement of weight is possible). It is generally accepted that the primary goal of transcription is to provide the information which is important, especially information that could not be supplied by applying a general rule. Since there are multiple systems of rules which could relate a less-accurate transcription that focuses only on important properties of speech to a highly accurate transcription that closely mimics actual speech, more than one transcription of "important" details is possible since there is more than one theory of which aspects are "important".

As an example, the word "soy" could be transcribed as [soy] or [sɔy], [sɔy] being somewhat closer to phonetic reality than [soy]. It may not be immedi-

ately obvious that [sɔy] is a phonetically more accurate transcription, but there is a simple instrumental way to address this question. By digitally recording sample words containing the relevant vowels and playing back just the center part of the vowel with a speech editing and playback program, one can compare the quality of the vowel [o] in words like "soap", "soak" with the vowel [ɔ] in "sought", and the round vowel in question in "soy". By eliminating distracting consonants, you can concentrate on the differences in vowel quality, and will probably conclude that the vowel in the middle of "soy" is closer to that of "sought" than it is to that of "soak".

There is no *contrast* (see the discussion in the next chapter) between [oy] and [ɔy] in English — no words are distinguished by having [oy] versus [ɔy] — so it is possible to transcribe this diphthong either way and relate that transcription to actual pronunciation by rule. In terms of satisfying the minimal criterion of accuracy — including all information which cannot be predicted — either transcription is as good as the other.

Since the transcription [sɔy] is closer to the phonetic output, that might decide the matter in favor of [sɔy]. Some countervailing considerations legitimise the transcription [soy]. First, [sɔy] is a somewhat closer-to-accurate transcription, but the quality of the vowel in this diphthong is still not the same as the quality of the vowel of "sought", "law", so to be fully faithful to the idea of representing pronunciations accurately, the transcription of "soy" should indicate that the vowel is somewhat tenser, something like [ɔ̝] (using the IPA diacritic for a raised vowel variant): but this is a vowel with no independent existence in English. Thus the choice between [soy] and [sɔy] is not a choice between a phonetically accurate and a phonetically inaccurate transcription insofar as neither transcription accurately captures the nature of the round vowel in this diphthong. Once we grant the legitimacy of relating the phonetic form [sɔ̝y] to a transcription [sɔy] which is not the same as the phonetic form, there is no reason in terms of phonetic accuracy to reject [soy] as an equally good transcription.

Second, the preference for [ɔ] in the transcription is predicated on the independent necessity of using both [a] and [ɔ] in transcriptions. But as we know, some dialects do not distinguish those vowels — "sot" and "sought" are pronounced the same in that dialect. The choice of writing [a] vs. [ɔ] for the vowel of these words is relatively arbitrary.[3] While the phonetic quality of "oy" in this dialect is also closer to [ɔy], there is no vowel [ɔ]. But we cannot write "oy" as [ay], since in this dialect [ɔy] is clearly different from [ay] ("buy" ≠ "boy").

Similar problems surround the transcription of "o" before "r": is the vowel in "core" better transcribed as [ɔ] or [o]. This question becomes particularly pertinent in dialects which do not have a difference between [ɔ] and [a]. Should the first

[3] The vowel which the author uses is phonetically distinct from both of the vowels [a] (more accurately the low central vowel [ɐ]) and [ɔ] used by speakers of dialects making the contrast, and is closer to — but still distinct from — the low back vowel [ɑ], found in Norwegian.

vowel in the diphthong "ay" be transcribed with the same vowel as in "hot"? Close inspection of pronunciation reveals that the vowel portion of the diphthong is closer to (IPA) [ɐ] in contrast to the vowel of "hot" which is closer to (IPA) [ɑ]. Similarly, there is no absolute necessity of distinguishing the vowels [ə] and [ʌ] in English: [ə] appears in unstressed syllables and [ʌ] appears in stressed syllables. While it would suffice to use a single vowel symbol to represent the vowels of "abutt", the transcription [əbʌ́t] more accurately reflects actual pronunciation, since the actual vowel quality is significantly affected by whether the vowel is stressed. Whether that fact is sufficient to warrant use of an additional symbolic distinction must rest on decisions about one's goal in transcription.

3

Allophonic Relations

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
- introduces the formalization of phonological rules

While a phonetically accurate representation of pronunciation is useful to phonology, the focus of phonology is not transcription of words, but is rather the mental rules which govern the pronunciation of words in a given language. Certain facts about pronunciation simply cannot be predicted by rule, for example that in English the word 'sick' is pronounced [sɪk] and 'sip' is pronounced [sɪp]. Hence one fundamental component of a language is a lexicon, which contains a list of words (or morphemes — parts of words), which must at the very least give any information which cannot be predicted by rules in the language. However there is often much about the pronunciation of words which can be predicted. For example, consider the pronunciation of the word 'tick' in English. The initial voiceless consonant 't' in this word is phonetically aspirated, so this word would be transcribed phonetically as [t^hɪk]. The presence of aspiration can be demonstrated visually by dangling a tissue in front of the mouth when saying this 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), so this word would be transcribed phonetically as [stɪk]. This fact of pronunciation can be predicted by rule, and we shall now consider how that prediction is made.

1. English consonantal allophones

Minimal pairs and contrasts. While the physical difference between *t* and t^h in English is just as real as the difference between *t* and *d*, there is a fundamental linguistic difference between these two relationship. The selection of *t* versus *d* may

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]
	dire	**t**ire
	do	**t**wo
	Dick	**t**ick
	dork	**t**orque
	ha**d**	ha**t**
	sai**d**	se**t**
	ben**d**	ben**t**

The difference between [t] and [d] is **contrastive** (also termed **distinctive**) in English, since it can form the sole basis for distinguishing different words (and thus, [t] and [d] **contrast**). The basis of that distinction is voicing. (English voiced stops do not always have phonetic vocal fold vibration, which depends on many factors, such as distance from the glottis to the consonantal contriction, or state of the glottis in neighboring sounds. These factors are in the domain of phonetics).

Phonemes and allophones. The choice of a voiceless aspirated stop versus a voiceless unaspirated stop, on the other hand, never defines the sole basis for differentiating words in English. The occurrence of [t] versus [t^h] (also [k] versus [k^h], and [p] versus [p^h]) follows a rule that aspirated stops are used in one phonological context, and unaspirated stops are used in all other contexts. In English, [t] and [t^h] are predictable variants of a single abstract segment, a **phoneme**, which we represent as /t/. These predictable variants are termed **allophones** — the sounds are in **complementary distribution** because the context where one variant appears is the complement of the context where the other sound appears. As we have emphasized, one concern of phonology is determining valid relations between surface phonetic segments and the abstract mental constructs, the phonemes, which represent the unity behind observed [t]~[t^h] etc. The implicit claim is that despite physical differences, [t] and [t^h] (idem [k] and [k^h], [p] and [p^h]) are in a fundamental sense 'the same thing': reducing physically realised [t t^h k k^h p p^h] to /t k p/ and supplying the information "realised as [t] vs. [t^h]" recognises these regularities.

1.1. Aspiration

We will turn our attention to some such rules of pronunciation in English, starting with aspiration, to see what some of these regularities are. In the first set of words below, the phonemes /p,t,k/ are aspirated whereas they are not aspirated in the second set of words.

(2) *Aspirated stops*

pool	[**p**^{h}uwl]	tooth	[**t**^{h}uwθ]	coop	[**k**^{h}uwp]
pit	[**p**^{h}ɪt]	tin	[**t**^{h}ɪn]	kill	[**k**^{h}ɪl]
apply	[ə**p**^{h}lay]	atomic	[ə**t**^{h}amɪk]	account	[ə**k**^{h}æwnt]
prawn	[**p**^{h}ran]	truth	[**t**^{h}ruwθ]	crab	[**k**^{h}ræb]
pueblo	[**p**^{h}wɛblow]	twine	[**t**^{h}wayn]	quill	[**k**^{h}wɪl]
play	[**p**^{h}leɪ]			clay	[**k**^{h}leɪ]
puce	[**p**^{h}yuws]			cube	[**k**^{h}yuwb]

(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**reɪ]	stray	[s**t**reɪ]	screw	[s**k**ruw]
split	[s**p**lɪt]			sclerosis	[s**k**lərowsɪs]
spew	[s**p**yuw]			skew	[s**k**yuw]

The selection of an aspirated versus an unaspirated voiceless stop is determined by the 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. 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[1] and unaspirated stops appear elsewhere.

We assume that the voiceless stops are basically unaspirated in English, and explain where aspirated segments appear 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 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 details in Chapter 4.

Actually, the issue of aspiration in English is a bit more complex. 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.

[1] See the Advanced Topics section at the end of the chapter for discussion of the status of the syllable as an phonetic property.

(4)	hǽ**p**iy	'happy'	k^{h}ǽm**p**ɪŋ	'camping'	hɛ́l**p**ɪŋ	'helping'
	lʌ́**k**iy	'lucky'	sʌ́**k**r̩	'sucker'	sɔ́l**t**iy	'salty'

Compare these words with seemingly analogous words where there is aspiration on the stop between vowels, such as [ə**t**^{h}ǽk] 'attack', [ə**k**^{h}yúwmyəleyt] 'accumulate', [léy**t**^{h}ɛ̀ks] 'latex', [ə**p**^{h}ɛ́ndɪks] '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'.

Alternations involving aspiration. The dependence of aspiration on the location of stress leads to discovering further evidence for the 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 (5) 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.

(5)	[ə**p**^{h}láy]	'apply'	[æ̀**p**lək^{h}éyšn̩]	'application'
	[sə**p**^{h}ówz]	'suppose'	[sʌ̀**p**əzíšn̩]	'supposition'
	[ə**k**^{h}wáyr]	'acquire'	[æ̀**k**wəzíšn̩]	'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*.

(6)	verb	subject noun	object noun	
	grǽn**t**	grǽn**t**r̩	grǽn**t**^{h}í	"grant"
	šíf**t**	šíf**t**r̩	šɪ̀f**t**^{h}í	"shift"
	hɛ́l**p**	hɛ́l**p**r̩	hɛ̀l**p**^{h}í	"help"
	čów**k**	čów**k**r̩	čòw**k**^{h}í	"choke"
	stráy**k**	stráy**k**r̩	strày**k**^{h}í	"strike"
	ət^{h}ǽ**k**	ət^{h}ǽ**k**r̩	ət^{h}æ̀**k**^{h}í	"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 [stɔrd] and [p^{h}almə], as predicted by the aspiration rule. The name Stavanger (Norway) may be pronounced many ways — [stəvǽŋr̩], [stǽvənǰr̩], [stəvǽnǰr̩], [stǽvəŋr̩] and so on, but consistent 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 [rǽpəlo], with no aspiration because /p/ is at the beginning of an unstressed syllable, or on the second syllable as in [rəp^{h}álo] — 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 [p^{h}al] "fruit" and [stan] "breast" are not difficult for English speakers to pronounce; accurate pronunciation of [pal] "want" and [st^{h}al] "place" on the other hand are. 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' [hǽpiy], 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 — [hǽ::]...[p^{h}ì::y]. All of these facts are explained by one simple hypothesis, that in English the occurrence of aspiration on stops derives from applying a rule.

1.2. Flapping

We now turn to another such phonological rule. A phonetic characteristic of many North American dialects of English is the phenomenon of 'flapping', where /t/ and /d/ become the flap [ɾ] in certain contexts, for example [wáɾr̩] "water". It is clear that there is no contrast between the flap [ɾ] and any other consonant of English: there are no minimal pairs such as hypothetical [hɪt] and *[hɪɾ], or *[bətr̩] and [bəɾr̩] 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 non-aspiration in the context v́Cv in (4) and (5), no examples included [t] as an intervocalic consonant. Now consider the following words:

(7)	a.	wáɾ̩	"water"	wéyɾ̩	"waiter; wader"
		ǽɾm̩	"atom; Adam"	ǽɾət^{h}ùwd	"attitude"
	b.	hít	"hit"	híɾɪŋ	"hitting"
		pót	"put"	póɾɪŋ	"putting"
		sɛ́t	"set"	sɛ́ɾɪŋ	"setting"

In the first group of examples, orthographic <t> is phonetically realized as the flap [ɾ] in the context V́_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. We could contemplate the possibility that we have uncovered an orthographic defect of English, since we have no letter which represents 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 3rd 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 which derives 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).

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

There is analogous evidence for an underlying /t/ in the word [ǽɾm̩] '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 [ət^{h}ámɪk] 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'. It is again important to note that the notion of 'vowel' used in this rule must include syllabic sonorants such as [r̩] for the preceding segment, and [r̩] or [m̩] for the following segment. Flapping is not limited to the voiceless alveolar stop /t/: underlying /d/ also becomes [ɾ] in this same context.

The theory of distinctive features given in Chapter 6 makes it easier to distinguish different notions of vowel and glide

(8)	Bare verbs	'One who V's'	'Ving'	
	bíd	bíɾ̩	bíɾɪŋ	"bid"
	háyd	háyɾ̩	háyɾɪŋ	"hide"
	wéyd	wéyɾ̩	wéyɾɪŋ	"wade"

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), and that is when /t/ is followed by a syllabic [n̩]. Consider, first, examples such as [bʌ́ʔn̩] 'button' and [ká̞ʔn̩] '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.

(9)	[rat]	'rot'	[raʔn̩]	'rotten'
	[hayt]	'height'	[hayʔn̩]	'heighten'
	[layt]	'light'	[layʔn̩]	'lighten'
	[fæt]	'fat'	[fæʔn̩]	'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 /n̩/ conditions the change of /t/ to [ʔ] in the context V́_n, i.e. when *t* is preceded by a stressed vowel and followed by an alveolar nasal. Words like [ǽɒm̩] "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.

(10)	Base verb	careful speech	casual speech
	hɪs	hɪsɪŋ	hɪsn̩
	rat	raɒɪŋ	raʔn̩
	flowt	flowɒɪŋ	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* [ʍɪʔniy] 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]. 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.

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 dialects, and instead the flapping rule applies. Some British dialects have a rule which applies in a rather different context e.g. [lɛʔə] "letter".

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 change 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. The consonants [l] and [d] are clearly separate phonemes in English, since the choice between these consonants is the only difference between words such as *lie* and *die* (speakers who contrast the vowels *a* and *ɔ* may further distinguish these words by choice of vowel), *log* and *dog* or *mill* and *mid*.

l and d in Setswana. However, in Setswana, there is no contrast between [l] and [d]. Phonetic [l] and [d] are contextually determined variants of a single phoneme: surface [l] appears before non-high vowels, and [d] appears before high vowels (neither consonant may come at the end of a word or before another consonant).

(11)	**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'
	me**d**isa	'make swallow'	**l**erumɔ	'spear'
	xoŋa**l**a	'to marry'	**l**eŋ	'when?'
	loxa**d**ima	'lightning flash'	**d**ǐǰɔ	'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'

Thus, Setswana has a rule which can be stated as '/l/ becomes [d] before high vowels'.

(12) l → d / ___ high vowel

This statement introduces the standard formalism for giving 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 classes of sounds (single segments like [l] or [d], or phonetic classes such as 'high vowel'), and B describes the nature of the change, either a phonetic parameter such as 'voiceless' or 'nasal', or simply a specific segment like [d]. The conditioning context might involve only a preceding element in which case "D" would be null, it might involve only a following element in which

case "C" would be null, or the applicability of the rule might depend on both what precedes and what follows. The arrow means 'becomes', the slash means 'in the environment' where the context is what follows the slash. The dash indicates the position of the affected segment in the relevant environment, so the environment 'C__D' means "when the affected segment is preceded by C and followed by D". Thus, rule (12) says "*l* becomes *d* when it stands before a high vowel" (and it does not matter what precedes *l*, since the rule says nothing about what precedes).

An equally accurate and general statement of the distribution or [l] and [d] would be '/d/ becomes [l] before non-high vowels'.

(13) 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 (12) or rule (13). 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), there is no contrast between [d] and [ǰ], or between [t] and [č]. The task is to inspect the examples in (14) and discover what factor governs the choice between plain alveolar [d,t] versus the alveopalatal affricates [ǰ,č]. In these examples, word-final sonorants are devoiced by a regular rule which we disregard, explaining the devoiced *m* in examples like [wah**č**um̥]

(14)	**ǰ**ihsk	'aunt'	**d**ɔʔaʔk	'mountain'
	ču:li̥	'corner'	**č**ɯwaʔgi̥	'clouds'
	wah**č**um̥	'drown'	**t**aht	'foot'
	ǰɯwɯhkɔh	'cut hair'	ʔahi**d**aʔk	'year'
	tɔnɔm̥	'be thirsty'	hɯh**t**ahpsp**č**u̥	'make it 5'
	hɯ**ǰ**ɯli̥	'self'	**č**ihkpan̥	'work'
	s**t**ah**t**ɔnɔm:ah	'thirsty times'	ʔi:**d**ḁ	'this'
	mɯḍɯ**d**am̥	'runner'	**t**ɔhn**t**n̥	'degenerate'
	tɔ**d**si**d**	'frighten'	**č**ɯpɔsi**d**	'brand'
	gah**t**wi̥	'to shoot'	**č**ɯh**č**i̥	'name'
	gɯʔɯ**d**tḁ	'get big'	**ǰ**umali̥	'low'
	tobi**d**k	'White Clay'	waʔ**ǰ**iwih	'swim'
	spa**d**mahkam̥	'lazy one'	**ǰ**u:ʔw̥	'rabbits'

We do not know, at the outset, what factor conditions the choice of [t,d] versus [č,ǰ] (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 organise 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 (14) and taking note of what comes immediately before any [t,d] versus [č,ǰ] we arrive at the following list of contexts.

(15) [t,d]: #__, h__, ɯ__, i:__, s__, i__, n__, ɔ__
[č,ǰ]: #__, 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.

(16) [t,d]: __ɔ, __a, __ḁ, __#, __s, __t, __k, __m, __w
[č,ǰ]: __i, __i̥, __u, __u̥, __ɯ

Only the vowels [i,u,ɯ] (and their devoiced counterparts) follow [č] and [ǰ], 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.

(17) alveolar → alveopalatal / ___ high vowel
stop affricate

The retroflex consonant [ḍ] does not undergo this process, as seen in [mɯḍɯdam̥].

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 (17). 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.

(18) alveopalatal affricate → alveolar stop / $\_\_ \begin{Bmatrix} \text{nonhigh V} \\ \text{C} \\ \# \end{Bmatrix}$

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 becomes 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.

(19)	**k**uur	'call!'	k**e**-**g**uur	'to call'
	ŋo**k**-**t**a	'dog'	ŋo**g**-ii**k**	'dogs'
	kɛ-**t**ɛ**p**	'request'	i-**t**e**b**-e	'you are requesting'
	ker	'look at!'	k**e**-**g**er	'to look at'
	pu**t**	'break up!'	k**e**-**b**u**t**	'to break up'
	poor	'thresh maize!'	k**e**-**b**oor	'to thresh maize'
	ŋelye**p**-**t**a	'tongue'	ŋelye**b**-we**k**	'tongues'
	kisi**p**či	'to follow for'	iŋ**g**urwe**t**	'pig'
	ki**p**k**i**rui	(name)	k**e**-**b**aa**k**p**a**a**k**	'to strip repeatedly'
	pʊn**b**ʊn	'soft'	**t**ilɑ**k**se	'it is cuttable'
	kir**g**i**t**	'bull'	**k**a**g**yam	'we ate'
	taa**p**tɛɛ**t**	'flower type'	**k**e**b**ri**t**ɑmɛɛ**t**	'to fall asleep'
	kɩ**b**laŋa**t**	(name)	**p**eeči**ŋ**e	'they are going for themselves'

In these examples, we can see that the 'peripheral' consonants — labials and velars — become voiced when they are both preceded and followed by vowels, liquids, nasals and glides: these are all sounds which are voiced.

(20) 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 begining or end of words, or [p,k] between vowels. (A student of phonology has a disadvantage compared to the child learning the language, since the language-learning child has access to a vastly larger set of examples and a much longer time to figure out the system).

Another very important clue in understanding the system is the fact that the actual pronunciation of morphemes changes 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'. In other words, when learning words in the language, the child is faced with changes in the actual pronunciation of words and word-parts — sometimes the root 'call' is pronounced [kuur] and sometimes it is pronounced [guur]. Similarly, in trying to figure out the root for the word 'dog', the 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 Kimatuumbi. The distinction between implosive and plain voiced consonants in Kimatuumbi can be predicted by a rule.

(21)	ɓɛɓɛɛlu	'male goat'	ɠundumuka	'be scared'
	ɓutuka	'flow'	ɠaala	'storage in roof'
	kɔɓɔkwa	'unfold'	ɓwʊʊmɪ	'life'
	kɔɔndwa	'dig clay'	ŋgaambalɛ	'fish sp.'
	ɓalaka	'luck'	ɠʊlʊya	'drive fast'
	lisɛɛŋgɛlɛ	'dowry'	ɓila	'without'
	ɠɔlɔya	'straighten'	ɠuna	'murmur'
	kiɓʊla	'towards Mecca'	kitʊʊmbɪ	'hill'
	kyaaŋgi	'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).

(22)	*to V*	*I should V*	
	ɠʊlʊka	ŋgʊlʊkɛ	'fly'
	ɠʊlʊya	ŋgʊlʊyɛ	'drive fast'
	ɠɔɔmba	ŋgɔɔmbɛ	'shoot a gun'
	ɠɔlɔya	ŋgɔlɔyɛ	'straighten'
	ɠuna	ŋgunɛ	'murmur'
	ɠundumuka	ŋgundumukɛ	'be scared'
	ɓalaaŋga	mbalaaŋgɛ	'count'
	ɓutuka	mbutukɛ	'flow'
	ɓʊʊka	mbʊʊkɛ	'leave'
	ɗuumu	nduumu	'continue'

Thus the pronunciation of the root 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 Kimatuumbi, it remains to decide whether the language has basically only plain voiced consonants, with implosives appearing in a special environment; or should we assume that Kimatuumbi 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 imposives 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 Setswana, a language may not provide empirical evidence which is the correct solution.

Now let us compare the two possible rules for Kimatuumbi: 'implosives appear word initially and after a vowel',

(23) $$C \rightarrow \text{implosive} \ / \ \begin{Bmatrix} V \\ \# \end{Bmatrix} \_\_$$

versus ‘plain consonants appear after a nasal’:

(24) 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 Kimatuumbi are basically implosive, and that the non-implosive 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 Kimatuumbi. Only a nasal may precede another “true” consonant, i.e. a consonant other than a glide. A different statement of the distribution of implosives versus plain voiced consonants for Kimatuumbi is that plain voiced consonants appear only after other consonants — due to the rules for permissible consonant combination in the language, the first of two true consonants is necessarily a nasal, so it is unnecessary to explicitly state that the preceding consonant in the implosive-to-plain-C rule is a nasal. Phonological theory does not always give a single solution for any given dataset, 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 cannot show which solution is right.

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

(25)	enɔ**q**	‘tree’	eno**q**	‘drum’
	e**k**et	‘house’	nči**k**u	‘I am buying’
	ne**k**	‘rope’	eywɑre**k**	‘sweet potato’
	ŋgɑ**q**	‘knife’	e**k**ɑ**q**	‘leg’
	etɔ**q**	‘town’	nyo**q**	‘porcupine’
	mə**k**	‘dirt’	nɑ**q**	‘brother in law’
	nde**k**	‘European’	pɔbri**k**	‘work project’
	betə**k**	‘job’	bepə**k**	‘to capsize’
	ti**k**u	(name)	**k**u	‘buy!’
	ɑyu**k**	(name)	esi**k**ɔŋ	‘pipe’
	kebwep	‘stammering’	ŋ**k**ɔ**q**	‘chicken’
	ŋ**k**ɑp	‘monet’	**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 non-high vowels *o, ɔ* or *a*, whereas velar *k* appears anywhere else.

(26) 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 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.

(27) $$q \rightarrow k \;/\; \left\{\begin{array}{c}\text{front V}\\ \text{central V}\\ \text{high back V}\\ \text{C}\\ \#\end{array}\right\} \_\_\_$$

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 classed, 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 6, namely that phonological rules operate in terms of phonetic classes of segments.

Arabela nasalization. Nasalization of vowels and glides is predictable in Arabela.

(28)	nẽẽkyææʔ	'lying on back'	mõnũʔ	'kill'
	tukuruʔ	'palm leaf'	sowakaʔ	'wall'
	nỹæ̃æ̃riʔ	'he laid it down'	suroʔ	'monkey'
	nĩĩkyææʔ	'is pouring out'	suwakaʔ	'fish'
	nityænũʔ	'carry on back'	šiyokwaʔ	'grease'
	posunãh̃ãʔ	'short person'	kuwɔxoʔ	'hole'
	nõõnũʔ	'be pained'	h̃ẽẽgiʔ	'termites'
	nãnããʔ	'he is bathing'	tæweʔ	'foreigner'

mããnũʔ	‘woodpecker’	h̃ỹũũššænõʔ	‘where I fished’
nĩnỹũʔ	‘to come’	mỹæ̃nũʔ	‘swallow’
nũw̃ãʔ	‘partridge’	h̃ũw̃ãʔ	‘a yellow bird’

Scanning the data in (28), 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] ([n**ĩĩ**kyææʔ] ‘is pouring out’ versus [šiy**o**kwaʔ] ‘grease’) or [n] ([mỹ**ã**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’. We discuss how vowels and glides are unified in Chaoter 6: for the moment, we will use the term **vocoid** to refer to the phonetic class of vowels and consonants.

(29) 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, given the following data?

(30)

abot	‘heavy’	agɨŋ	‘big’
amĩs	‘sweet’	anõm	‘young’
awon	‘bad’	basɨr	‘wet’
konẽŋ	‘yellow’	bɨrɨm	‘red’
eŋgal	‘new’	gəddɛ	‘big’
gandula	‘purple’	mãhãl	‘expensive’
mãhĩr	‘skillful’	mɨ̃rɨ	‘uncertain’
mõhẽhẽd	‘poor’	bumĩ	‘house’
mərri	‘duck’	hampaŋ	‘lightweight’
mãhãsiswa	‘student’	mãnũk	‘bird’
mãũŋ	‘tiger’	mĩãsih	‘true love’
mĩliar	‘billion’	mĩñãk	‘oil’
mũãra	‘confluence’	pamõhãlan	‘impossible’
mãẽn	‘play’	mãõt	‘die’
buʔuk	‘hair’	nãʔãs	‘get worse’

mãʔãp	‘excuse me’	mãhĩ	‘enough’
nẽwak	‘catch’	tiʔis	‘cold’
čaʔaŋ	‘pale’	mĩʔĩs	‘leak’

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 (31).

(31)	abuabu	‘grey’	bəddil	‘gun’
	gəttih	‘blood’	akar	‘root’
	səddih	‘sad’	asin	‘salty taste’
	bərrəkkah	‘useful’	bagoŋ	‘wild pig’
	bulao	‘blue’	babi	‘pig’
	kayas	‘pink’	kinã	‘quinine’
	čəppil	‘ear’	təbbih	‘far’
	bapa	‘father’	ləbbu	‘ash’
	bɨbɨr	‘belt’	ŋə̃ppel	‘sweep’
	mə̃ssin	‘machine’	bənnə̃r	‘correct’
	bulan	‘moon’	jənnə̃ŋŋã̃n	‘name’
	panãs	‘hot’	mə̃ddəm	‘dark’
	hukum	‘law’	sərrat	‘letter’
	səppuh	‘old’	bəkkeh	‘open a can’
	gəddaŋ	‘papaya’	sɨkɨt	‘sharp’
	kamẽ̃ja	‘shirt’	pačul	‘shovel’
	bənnãŋ	‘thread’	dada	‘torso’
	batu	‘stone’	mũrid	‘student’
	pəttis	‘fish sauce’	ǰaŋkuŋ	‘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: what is the generalization regarding where long versus short vowels appear (here, accent marks are used to indicate stressed vowels)?

(32)	ranahé:zʌ̃s	‘he trusts her’	ragé:das	‘he scrapes’
	í:geks	‘I eat it’	odá:we	‘flea’
	gadá:dis	‘I talk’	ʌ̃khní:nũʔ	‘I will buy it’
	sdʌ̃́:ha	‘a little bit’	aplám	‘Abram’
	ʌ̃gá:radeʔ	‘I lay myself down’	dʌ̃́:gehgweʔ	‘I’ll lift it’

rayʌ̃́thos	‘he plants’	yégreks	‘I push it’
wísk	‘five’	royóʔdeʔ	‘he works’
aweryáhsa	‘heart’	yágwaks	‘they and I eat it’
ísgʌ̃s	‘you sg. see her’	gatgáhthos	‘I look at it’
yokékhaʔ	‘it's burning’	ʌ̃gídyeʔ	‘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 [wísk]. 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 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.

Since there is no lexical contrast between long and short vowels in Mohawk, we assume that all vowels have the same underlying length: either all vowels are underlyingly long and are shortened in one context, or all vowels are underlyingly short and are lengthened in the complementary context. We cannot know for certain what the underlying representation of words is, but certain hypotheses about underlying forms in a given language result in simpler grammars which capture generalizations about the language more directly than do other hypotheses about underlying forms. If you assume that all vowels in Mohawk are underlyingly long, you must devise a rule which derives 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 account 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 of voiceless stops can be predicted in Ossetic.

(33)	t^həχ	‘strength’	k^hɔttag	‘linen’
	t^has	‘danger’	χɔstɔg	‘near’
	ɔftən	‘be added’	lɔppu	‘boy’
	fadat^h	‘possibility’	k^hastɔn	‘I looked’
	t^{sh}ɔst	‘eye’	k^hark^h	‘hen’
	akkag	‘adequate’	dəkkag	‘second’
	t^{sh}əppar	‘four’	t^{sh}ət^h	‘honor’
	t^{sh}əχt	‘cheese’	k^hɔm	‘where’
	fɔste	‘behind’	k^hom	‘mouth’

p^hirən	'comb wool'	zaχta	'he told'
χɔskard	'scissors'	χɔston	'military'
p^hɔrrɔst	'fluttering'		

Since both aspirated and plain consonants can appear at the end of the word ([t^{sh}ɔst] 'eye' versus [t^{sh}ət^h] 'honor'), the following context alone cannot be what governs aspiration. Focusing on what precedes the consonant, we see that aspirates appear in word initial position, or when preceded by a vowel or [r] (i.e. a sonorant) at the end of the word; unaspirated consonants appear when preceded or followed by an obstruent. Notice that it is easier to arrive at a unified generalization regarding where the unaspirated consonants appear than it is to state the context for aspiration. While it would be possible to start with underlying unaspirated consonants (as we did for English) and predict where aspiration is assigned, a simpler description of the relation between aspirated and unaspirated consonants emerges if we start from the assumption that all voiceless stops are basically aspirated in Ossetic, and deaspirate a consonant if it is next to an obstruent.

Optional rules. Sometimes rules of pronunciation are optional, which means that there will be two or more systematically related pronunciations for words, where there is no linguisticically-determined conditioning factor controlling this choice: this is often known as "free variation". Thus in Shimakonde, the phoneme /š/ can be pronounced as either [s] or [š] by speakers of the language: the same speaker may use [s] one time and [š] another time. The verb 'read' is thus pronounced as *šoomya* or as *soomya*, and 'sell' is pronounced as *šuluuša* or as *suluusa*. We will indicate such variation in pronounciation by giving the examples as '*šuluuša* ~ *suluusa*', meaning that the word is pronounceable either as *šuluuša* or as *suluusa*, as the speaker chooses. Such apparently unconditioned fluctuations in pronunciation are the result of a rule in Shimakonde which turns /š/ into [s]: this rule is optional. The optional nature of the rule is indicated simply by writing 'optional' to the side of the rule.

(34) š → 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 /šoomya/, the pronunciation [šoomya] results if the rule is not applied, and [soomya] results if the rule is applied.

Optional rules may have environmental conditions on them. In Kimatuumbi, as we have seen in (21), voiced stops are implosive except after a nasal. The voiced velar stop exhibits a further complication, that after a vowel (but not initially) underlying /ɡ/ optionally becomes a fricative [γ] (the symbol "~" indicates "may also be pronounced as").

(35)	ɓaɡana	~	ɓaɣana	"divide"
	ɓiliɡana	~	ɓiliɣana	"wrestle"
	ɓulaɡa	~	ɓulaɣa	"kill"
	ɡalaambuka	~	(*ɣalaambuka)	"change"

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

(36) ɡ → ɣ / V ___ (optional)

Typically the factors that determine which variant a speaker uses are individual and sociological, reflecting the various social factors such as age, ethnicity, gender, and geography, inter alia. A phonological account does not try to explain why people make the choices they do: that task 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 an idiosyncratic pattern of a particular word, and no speaker says [mæks] for 'mask', or [fɪsk] 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. From the perspective of grammars as objects describing the linguistic competence of individuals, an optional rule is countenanced only if the speak can actually pronounce words in multiple ways. In the case of Shimakonde, some speakers actually pronounce /šoomya/ in two different ways.

Summary

Some aspects of pronunciation, which are *contrastive*, cannot be predicted by rule, but other *allophonic* details can be supplied by rule. Allophonic changes are one 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 arrives at hypotheses by looking for regularities in the distribution of one sound versus others, and attempts to reduce multiple surface segments to one basic segment, a *phoneme*, the related segments being derived 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: Huichol

Inspect the distribution of [β] and [w], and see whether one segment can be predicted from the other by rule: state the rule, if it is possible.

wana	'over there'	pakawɨ	'it is hanging'
pɨwaki	'it is dry'	kawaya	'horse'
nakaβe	'earth deity'	βižarika	'Huichol Indian'
wakaži	'cow'	netaβi	'my chest'
newarikaɨ	'my mother in law'	βeʔeme	'prominent person'
kamaβi	'sweet potato'	tiβe	'jaguar'
taβekame	'drunkard'	nekaɨwari	'my stepfather'
βiki	'bird'	niwa	'come!'

2: Kikuria

Provide rules to explain the distribution of the consonants [β,r,γ] and [b,d,g] in the following data. Accents mark tone: acute is H tone and 'hacek' [ˇ] is rising tone.

aβaánto	'people'	aβamúra	'young men'
amahíindi	'corn cobs'	amakɛ́ɛ́ndɔ	'date fruits'
eβă	'forget!'	eeŋgwɛ́	'leopard'
eγă	'learn!'	ekeβwɛ́	'fox'
hoorá	'thresh!'	iβiγúrúβe	'small pigs'
iβirúúŋgúuri	'soft porridges'	iβitúúmbe	'stools'
ichiindéme	'tongues'	βáinu	'you (pl)'
ichiiŋgɛ́na	'grinding stones'	ichiiŋgúrúβe	'pig'
γaβă	'share!'	ichiiŋgúta	'walls'
βɛrɛká	'carry a child!'	iγitúúmbe	'stool'
irihíindi	'corn cob'	βoryó	'on the right'
irikɛ́ɛ́ndɔ	'date fruit'	mbaryoómána	'they will quarrel'
mbaryoórá	'they will float'	γúúká	'ancestor'
óγá	'be sharp!'	oβoβééβe	'badness'
rɛɛntá	'bring!'	oβoγááká	'male adulthood'
oβotééndééru	'smoothness'	okoγéémbá	'to cause rain'
okoómbára	'to count me'	okoóndɔ́γa	'to bewitch me'
okoóŋgókă	'to be clear'	omoγóóndo	'plowed field'
ooŋgóka	'be clear!'	remă	'weed!'
romă	'bite!'	teγetá	'be late!'
uβukúúŋgu	'female adulthood'	uγusíri	'huge rope'
ukuúmbuuryá	'to ask me'	uruγúta	'wall'

3: Modern Greek

Determine whether the two segments [k] and [k^y] are contrastive or are governed by rule; similarly, determine whether the difference between [x] and [x^y] 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^yino	'pour'	k^yino	'move'
krima	'shame'	xrima	'money'
xufta	'handful'	kufeta	'bonbons'
kali	'charms'	xali	'plight'
x^yeli	'eel'	k^yeri	'candle'
x^yeri	'hand'	ok^yi	'a weight'
ox^yi	'no'		

4: Farsi

Describe the distribution of the trill [*r̃*] and the flap [*ř*].

ær̃teš	'army'	far̃si	'Persian'
qædři	'a little bit'	r̃ah	'road'
r̃ast	'right'	r̃iš	'beard'
ahar̥̃	'starch'	axær̥̃	'last'
hær̃towr̥̃	'however'	šir̥̃	'lion'
ahaři	'starched'	bæřadær̥̃	'brother'
čeřa	'why?'	dařid	'you have'
biřæng	'pale'	širini	'pastry'

5: Osage

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

dábri	'three'	áðikhã žã	'he lay down'
dačpé	'to eat'	čʔéðe	'he killed it'
dakʔé	'to dig'	ðéze	'tongue'
dáli	'good'	ðíe	'you'
daštú	'to bite'	ðíški	'to wash'

6: 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!'
yɛlĭjlĭj	'grandchild'	mayɛt	'see'
gənzəb	'money'	ǰɛgna	'brave'
nəñ	'I am'	məwdəd	'to like'
mənnəsat	'get up'	məmkər	'advise'
žɛle	'unarmed'	yɛlləm	'no'
məč	'when'	məst'ət	'give'
fəlləgə	'he wanted'	agəññɛ	'he found'
təməččɛ	'it got comfortable'	mokkərə	'he tried'
k'ažžɛ	'he talked in his sleep'	žɛmmərə	'he started'
lačč'ɛ	'he shaved'	aššɛ	'he rubbed'
bəkk'ələ	'it germinated'	šɛməggələ	'he became old'

7: Gen

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

agble	'farm'	agoŋglo	'lizard'
aŋəli	'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'
črɔ̃	'exterminate'	ñrã	'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'
eñrɔ̃	'spitting cobra'	ǰro	'hint'

8: Kishambaa

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 Kishambaa.

tagi	'egg'	kitabu	'book'	paalika	'fly!'
ni	'it is'	ŋombe	'cow'	matagi	'eggs'
dodoa	'pick up'	goša	'sleep!'	babu	'skin'
ndimi	'tongues'	ŋgoto	'heart'	mbeu	'seed'
n̥tʰumbii	'monkey'	ŋ̊kʰuŋguni	'bedbug'	m̥pʰeho	'wind'

9: Thai

The obstruents of Thai are illustrated below. Determine what the obstruent phonemes of Thai are ([pˀ, tˀ and kˀ] are unreleased stops). Are [pˀ, tˀ, kˀ] 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'	müü	'hand'
rakˀ	'love'	baa	'crazy'
loŋ	'go down'	brüü	'extremely fast'
haa	'five'	plaa	'fish'
dii	'good'	čaan	'dish'
tʰee	'pour'	tʰruumɛɛn	'Truman'
kʰɛŋ	'hard'	panyaa	'brains'
ləəy	'pass'	pʰyaa	[title]
lüakˀ	'choose'	klaaŋ	'middle'
čʰatˀ	'clear'	traa	'stamp'
riipˀ	'hurry'	ɔɔkˀ	'exit'
pʰrɛɛ	'silk cloth'	kiə	'wooden shoes'
kʰwaa	'right side'	kɛɛ	'old'
dray	'drive (golf)'	düŋ	'pull'
kan	'ward off'	čuəkˀ	'pure white'
pʰleeŋ	'song'	čʰan	'me'
staaŋ	'money'	rapˀ	'take'
yiisipˀ	'twenty'	pʰaa	'cloth'
kʰaa	'kill'	dam	'black'
raay	'case'	titˀ	'get stuck'
sipˀ	'ten'	pen	'alive'

10: 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'

11: Quechua (Cuzco dialect) (advanced)

Describe the distribution of the following four sets of segments: k, x, q, χ; ŋ, N; 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), and provide a rule which accounts for all occurrences of the predictable variant. {Reminder: N is a uvular nasal}

qori	'gold'	čoχlu	'corn on the cob'
q'omir	'green'	niŋri	'ear'
moqo	'runt'	hoq'ara	'deaf'
phul^{y}u	'blanket'	yuyaŋ	'he recalls'
tul^{y}u	'bone'	api	'take'
suti	'name'	oNqoy	'be sick!'
čilwi	'baby chick'	č^{h}ičiŋ	'be whispers'
č^{h}aNqay	'granulate'	aNqosay	'toast'
qečuŋ	'he disputes'	p'isqo	'bird'
musoχ	'new'	čuŋka	'ten'
yaNqaŋ	'for free'	čul^{y}u	'ice'
q^{h}el^{y}a	'lazy'	q'eNqo	'zigzagged'
čeqaŋ	'straight'	qaŋ	'you'
noqa	'I'	čaxra	'field'
čeχniŋ	'he hates'	soχta	'six'
aχna	'thus'	l^{y}ixl^{y}a	'small shawl'
qosa	'husband'	qara	'skin'
alqo	'dog'	seNqa	'nose'

karu	‘far’	atoχ	‘fox’
qaŋkuna	‘you pl.’	pusaχ	‘eight’
t’eχway	‘pluck’	č’aki	‘dry’
wateχ	‘again’	aŋka	‘eagle’
waχtay	‘hit!’	haku	‘let’s go’
waqay	‘tears’	kaŋka	‘roasted’
waxča	‘poor’	waleχ	‘poor’
t^hakay	‘drop’	reχsisqa	‘known’

12: Lhasa Tibetan (advanced)

There is no underlying contrast in this language between velars and uvulars, or between voiced or voiceless 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: [G] represents a voiced uvular stop]

aŋgu	‘pigeon’	aŋṭãã	‘a number’	aŋba	‘duck’
apsoo	‘shaggy dog’	amčɔɔ	‘ear’	tukṭüü	‘poison snake’
amto	‘a province’	ɨγu	‘uncle’	ɨmči	‘doctor’
uṭɨ	‘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’	qaaβo	‘white’
kɨkṭi	‘belch’	kɨβu	‘crawl’	kɨɨŋguu	‘trip’
kik	‘rubber’	kiṭuu	‘student’	kɪɪcuu	‘translator’
kɪɪrii	‘roll over’	kiiγuu	‘window’	ku	‘nine’
kupcɨ	‘900’	kupcaa	‘chair’	kɛnca	‘contract’
kɛmbo	‘headman’	keγöö	‘head monk’	kerβa	‘aristrocrat’
qo	‘head’	qomba	‘monastery’	qɔr	‘coat’
qɔɔʁɔɔ	‘round’	$č^h$eʁa	‘half’	$č^h$uγum	‘cheese’
topcaa	‘stairs’	t^hoʁõõ	‘tonight’	ṭaaʁãã	‘post office’
ṭuγɨ	‘harbor’	ṭuNGo	‘China’	nɛNGaa	‘important’
paNGɔɔ	‘chest’	pɛɛβãã	‘frog’	simGãã	‘build a house’

Suggestions for further reading

Harris 1994 and Kahn 1976 provide more discussion of English consonant allophones. Sapir 1925 is the classic work discussing the phoneme as a mental representation of physical sound.

Advanced Topics and Readings

The Phoneme. The invention of the term 'phoneme' is generally credited to Baudoin de Courtenay (1895). Concepts along this line have been attributed to the Indic grammarian Patanjali (appr. 3rd century BC), the anonymous author of *Fyrsta Málfrøðiritgerðin* ("The First Grammatical Treatise"), a treatise on Icelandic written around 1150, and to King Sejong, the inventor of the Korean alphabet in the 15th century. The conceptual content of the term has been the subject of tremendous controversy. Sapir viewed the phoneme as a psychological entity, stating (1925) "This is the inner configuration of the sound system of a language, the intuitive 'placing' of the sounds with reference to one another". But Twaddell 1935 rejects the mentalist definition of the phoneme, stating "Such a definition is invalid because (i) we have no right to guess about the linguistic workings of an inaccessible 'mind'...". The operational versus a psychological characterization of the phoneme has played a major role in phonological theory.

The conception of "phoneme" which played the most important (negative) role in the development of contemporary phonology is that of the so-called "taxonomic phoneme", the view prevalent in American structuralist linguistics prior to the 1960's. The historical importance of this conception of phoneme is that it was the target of attacks by Halle 1959, Chomsky 1964, Chomsky & Halle 1965 and Postal 1968, inter alii, in works establishing the basis for generative phonology. The taxonomists essentially viewed the phoneme as just a means of organising data — as behaviorists, they attribute no mental status to phonemes (indeed, the concept 'mind' was outside the purview of behaviorism). In that school of linguistics, special emphasis is put on analytic procedures and formal analysis (befitting its roots in logical positivism, which swept science in the 1930's). Under this view, primary emphasis was put on formally defining analytic levels, stating the formal alphabet of symbols used at a given level of analysis, and stating the mathematical relation between levels. It was assumed that, given suitable technological progress, a phonemic analysis could be arrived at automatically from a large enough corpus. Bloch 1948, fn.7 states "Given a sufficient sample of the dialect — say twenty or thirty hours of connected speech by an informant, recorded either on a high-fidelity machine or in a minutely accurate phonetic transcription — a linguist could probably work out the phonemic system without knowing what any part of the sample meant, or even whether any two parts meant the same things of different things".

Under this view, 'phones' are the objects closest to physical sound waves: they are, essentially, narrow phonetic transcriptions.[2] 'Phonemes' are objects at the next most abstract level, and are seen as sets of phones. Thus Hockett 1942

[2] The development of this theory largely predates the development of instrumental techniques for measuring the physical properties of speech, so relatively little could be said about physical properties of speech at that time.

says that "A phoneme is a class of phones determined by six criteria", using a logician's term "class" that is similar to the concept "set". The relation between phonemes and phones is (for some analysts) said to be subject to the formal condition *biuniqueness* (Harris 1944) which guarantees free interchangeability of letters across levels. This condition requires that any phoneme in a given context be represented by one phone, and that a given phone be a member of exactly one phoneme: phonemes must not intersect (Bloch 1948). This guarantees that you can predict the actual pronunciation of a word from the phonemic transcription aided with knowledge of the allophonic rules in the language. Just based on hearing a sound and knowing the mapping between phones and phonemes in a language, you can determine what phoneme it is a member of. The phoneme /t/ in English in word-initial position always maps to an aspirated [t^h], and the phone [t^h] always maps to the phoneme /t/.

The analytical acid test for determining phonemic status, then as now, is the minimal pair. Thus [p] and [p^h] are not distinct phonemes in English: the contexts where [p] appears are the complement of those where [p^h] appears; therefore, the phones [p] and [p^h] are members of one phoneme, /p/ (and [p], [p^h] are the allophones of /p/). A comparison of /p/ and [p] is meaningless in this theory, since /p/ is an object at the phonemic level but [p] is an object at the phonetic level: comparisons of objects is possible only within a level. The pair /p/ and /b/, are separate phonemes, as shown by minimal pairs such as /pɪl/ vs. /bɪl/, distinguished only by selection of /p/ versus /b/.

While this seems straightforward, problems arose in attempting to define the analytic procedures for phonemic versus allophonic status. Chao 1934 noted that in Beijing Mandarin, the palatalized alveopalatal phones [$\check{c}^y$ $\check{c}^{hy}$ $\check{s}^y$] only appears before the high front vowels [i,ü], whereas the velar [k k^h x], alveolar [t^s t^{sh} s] and plain alveopalatal phones [č $\check{c}^h$ š] do not appear before these vowels. In other words, [$\check{c}^y$ $\check{c}^{hy}$ $\check{s}^y$] are in complementary distribution with [k k^h x], but they are also in complementary distribution with [t^s t^{sh} s] and [č $\check{c}^h$ š]. Grouping of phones which are in complementary distribution into a single phoneme was not an optional analytical step within the taxonomic framework. Reduction of the size of the phonemic inventory was considered to be one of the most important goals of analysis (an assumption which has, for better or worse, been largely carried over into contemporary phonology). Therefore, the option of granting [$\check{c}^y$ $\check{c}^{hy}$ $\check{s}^y$] the status of being phonemes themselves was not available. The theory provides no other means of deciding what phoneme [$\check{c}^y$ $\check{c}^{hy}$ $\check{s}^y$] belong to, so an arbitrary decision has to be made as to what phonemes these sounds represent: but arbitrary decisions are as much anathema to science as unwanted complexity is.

A problem pointed out by Halle 1959 is that this view of phonemes leads to a disunified treatment of phonological processes which should intuitvely be unified. Russian has a regressive voicing process where obstruents agree in voicing with the following obstruent. Accordingly, the velar fricative *x* is pronounced [γ] and the alveolar fricative *s* is pronounced [z] before a voiced obstruent. Russian

does not have a voiced velar fricative phoneme: [γ] is in complementary distribution with [x], and these phones are members of the same phoneme. But /s/ and /z/ are contrasting phonemes of Russian. According to existing taxonomic analytic procedures, the rule relating [x] and [γ] is an allophonic rule on one level, and the rule which accounts for the alternation between *s* and *z* must be at a separate level — it is a "morphophonemic" rule.

Another problem faced by this particular concept of the phoneme is the flapping process in English. It is generally held that the flap [ɾ] is not a phoneme of English. However, flapping affects both *t* and *d*, so that (in some dialects) "writer" and "rider" are homophonous. The principle of biuniqueness disallows a surface phone from being a member of one phoneme (*t*) in some words but another phoneme (*d*) in other words: many-to-one mapping are allowed only between morphophonemes and phonemes.

Joos 1957 contains a collection of essential readings covering more than 30 years of the American structuralist tradition, and original sources should be consulted to understand the development of the phoneme, since "American Structuralism" is not a single monolithic theory. The problem of Russian voicing would probably not have been so serious for Bloomfield's view of the phoneme as for Bloch's. Other conceptions of phoneme existed as well, exemplified by Trubetzkoy 1939, Firth 1939, Jakobson 1949, Jones 1950, Martinet 1952 and others.

Generative phonology largely rejected the phoneme as a significant unit of analysis, replacing it instead with concepts like the "bundle of distinctive feature values" which defines the symbolic sound unit distinct from physical sound waves (see Chapter 6), and "underlying form" (see Chapter 4) which covers the distinction between sounds that can form lexical distinctions such as /t/ versus /d/, and those that do not ([t] and [t^h], the latter always arising by a rule in English). Various scholars working in the generative tradition have suggested that the phoneme has some utility, for example Schane 1971, but it remains unclear exactly which concept of phoneme will turn out to be most useful, and to what extent "phoneme" is a part of grammatical theory.

Allophonic rule versus phonetic implementation. Another important question regarding allophonic rules and the distinction between phonetics and phonology is whether all allophonic rules are indeed part of phonology, which brings us back to asking whether a dividing line can be drawn between phonetics and phonology. In some versions of generative phonology, for example Chomsky & Halle 1968, no such line is drawn, and what might now be considered "rules of phonetic implementation" would be seen as just another kind of phonological rule (the primary import of Halle's argument against the taxonomic phoneme was that there is no fundamental difference between phonetics and phonology).

Under the conception of the phonology / phonetics distinction proposed here, a process which operates in terms of continuous values and actual physical properties would be in the domain of phonetics, and one which operates in terms of

discrete symbolic units is in the domain of phonology. A rule which makes the voiceless units *p, t, k* become voiced units *b, d, g* between vowels would be a phonological process, whereas a process which decreases the size of a glottal opening gesture and increases the speed of a constriction-forming gesture would be a phonetic process. The difficulty lies in determining which is a better characterisation of a given process, since the phonological process of intervocalic voicing could also be described in terms of the physical conseqences of symbol substitution.

The implication behind a phonological account of a process is that the grammar definitively selects one of two different outputs — [t] or [t^h] — befitting the discrete nature of phonological processes. Since the physical output is a continuum, and since phonetics is particularly about how discrete symbols are realised in continuous physical reality, the discovery that the proper description of a process accesses a continuum of values precludes the process from being treated phonologically. As emphasised in the preceding chapters, phonology considers language sounds as being drawn from a small inventory of possibilities: a phonological description does not countenance the postulation of an unlimited set of entities, such as [t] versus [t^{h}], [t^{h}], [t^{h}], [t^{h}] and so on, with different sized *h*'s iconically representing greater degrees of aspiration (See Chapter 6 for the theoretical basis for restricting the number of distinctions in a phonological account).

Regardless of how this theoretical matter is resolved, you should be aware that processes which have been represented as categorical choices between one segment versus another might in reality be an analysist's imposition of categoriality on an actually continuous process. It is often presumed that English has an allophonic rule of regressive nasalization, whereby /dɛn/ becomes [dɛ̃n], changing an oral vowel into a nasal vowel. However Cohn 1993 shows that the timing of nasal airflow in English /dɛn/ is quite different from the timing of nasal airflow in French, which has phonemically contrastive oral and nasal vowels — where nasality is incontroversially phonological. The prediction of the phonological account of English vowel nasalisation is that the vowel should be completely nasal, but Cohn's results show that the vowel is only nasal on the second half. It is simply the limited precision of impressionistic transcriptions that has caused scholars to conclude that a pre-nasal vowel in English has "become nasal", in a categorical sense.

One analysis of the Marshallese vowel system (Bender 1963) assumes a large inventory of vowels, including [i e ɛ ɯ ʌ a u o ɔ] plus various diphthongs. Bender 1968 reanalyses the system as having just a set of phonological central unrounded vowels, deriving the remaining surface vowels by allophonic rules, whereby surface vowel quality is parasitic off of secondary articulations of the preceding and following consonant (thus, [e] only appears between palatalised consonants, [o] only appears between rounded consonants). Choi 1992 in a phonetic study of Marshallese argues that the most accurate description derives the supposed vowels [e], [o] and various diphthongs from the *surface* vowel (symbolically speaking) [ʌ]. Thus, [e], [o] and so on are not actually part of the phonological grammar of Marshallese, and the quality perceived as [e] arised because the pattern

of phonetic timing of articulators. Under Choi's view, all that the grammar of Marshallese (i.e. the symbolic, categorical computations) contains is a set of palatalized, rounded and velarized consonants, and the vowels [ɯ ʌ a] (not "definitely unrounded and central", rather "not definitively round or non-round" etc. — a set of "vague" vowels lacking conventional symbols). In the phonetic-implementation approach to Marshallese vowels, as far as the grammar is concerned what sounds like *l*^{w}*ɔŋ*^{w} "housefly" is just surface phonologically [l^{w}aŋ^{w}], but because of the way articulator movement works in this language, this sounds like [l^{w}ɔŋ^{w}].

English consonant allophones. Kahn 1976 is a basic reference on the relevance of the syllable to aspiration, flapping and glottalization in English. Since the point of our discussion of consonant allophones in section 1 is to familiarize the student with the notion of allophonic variation, the full range of conditions on these rules are not investigated. For example, aspirated and flapped /t/ actually contrast in 'capitalistic' [k^{h}æ̀pəɒəlí̀stɪk] versus 'militaristic' [mì̀lətr̩ɾí̀stɪk], the reasons presumably having to do with the difference between stress (hence aspiration) in 'cápital' versus 'mílitàry'. Other contemporary references on English consonant allophony include Kiparsky 1979, Selkirk 1982, Withgott 1982, Harris 1994, and de Jong 1998. There are numerous traditional descriptions of English pronunciation, including Jones 1956, Trager & Smith 1951, and Gimson 1962.

Syllable position is important in understanding English allophony, but the syllable has an uncertain status in phonology. Unlike 'voicing' or 'nazalization' which have fairly clear acoustic and articulatory definitions, the syllable is an abstract organisation of sequences of segments. The number of syllables in a word and what are the boundaries of each syllable is not resolvable by close observation. Arguments for the syllable instead focus on what is explained by positing the syllable (and positing particular organisations of segments into syllables.

In the case of word like *sit*, it is generally accepted that there is a single syllable, which begins with *s* and ends with *t* — however, the theory of Government Phonology (Kaye, Lowenstamm & Vergnaud 1990) opens the possibility that this word is disyllabic with an empty nucleaus after *t*. In the case of a single consonant between vowels, such as the *m* in *amount*, we will assume that *m* belongs to the second syllable. One way to determine where syllables begin and end is to have a native speaker of English pronounce a word very slowly, in which case typically one would hear [ə]....[mæwnt] and not *[əm]....[æwnt]. Such a procedure does not directly reflect grammar, so these results have to be filtered through a theory of "what speakers are doing"; such an extralinguistic theory would explain why some speakers of Amharic have the intuition that [gənzəb] 'money' has four syllables — it has four letters in the standard writing system, and Amharic speakers understand that they have a "syllabic" writing system.

The best arguments for the syllable then are those — such as given in Kahn 1976 — which show that the assumption of a syllable provides a simple explanation for rules of consonant allophony in English.

4

Underlying Representations

This chapter looks deeper into the nature of underlying forms by

- introducing contrast-neutralizing rules
- seeing how unpredictable information must be part of the underlying form
- learning what factors are most important in establishing an underlying representation
- understanding how underlying forms are different from actually pronounced words

A fundamental characteristic of the rules discussed up to this point is that they have been totally predictable allophonic processes, such as aspiration in English or vowel nasalization in Sundanese. For such rules, the question of the exact underlying form of a word has not been so crucial, and in some cases a clear decision could not be made. We saw that in Sundanese every vowel becomes nasalized after a nasal sound, and every phonetic nasal vowel appears after a nasal. Nasality of vowels can always be predicted by a rule in this language: all nasal vowels appear in one predictable context, and all vowels are predictably nasal in that context. It was therefore not crucial to indicate whether a given vowel is underlyingly nasal or underlyingly oral. If you assume that vowels are underlyingly oral you can write a rule to derive all of the nasal vowels, and if you contrarily assumes that vowels are all underlyingly nasal you could write a rule to derive all of the oral vowels. The choice of underlying sound may make a considerable difference in terms of simplicity and elegance of the solution, and this is an important consideration in evaluating a phonological analysis, but it is possible to come up with rules which will grind out the correct forms no matter what one assumes about underlying representations in these cases. This is not always the case.

1. The Importance of Correct Underlying Forms

Neutralizing rules, on the other hand, are ones where two or more underlyingly distinct segments have the same phonetic realization in some context due to the application of some rule — thus the distinction of sounds is neutralized. This means that if you consider the word just in the neutralizing context, it is impossible to know which one the underlying segment is. Such processes require that

one pay particular attention to maintaining appropriate distinctions in underlying forms.

Consider the following examples of nominative and genitive forms of nouns in Russian, focusing on the final consonant found in the nominative.

(1)

Nominative singular	**Genitive singular**	**Meaning**
vagon	vagona	'wagon'
avtomobil^{y}	avtomobil^{y}a	'car'
večer	večera	'evening'
muš	muža	'husband'
karandaš	karandaša	'pencil'
glas	glaza	'eye'
golos	golosa	'voice'
ras	raza	'time'
les	lesa	'forest'
porok	poroga	'threshold'
vrak	vraga	'enemy'
urok	uroka	'lesson'
porok	poroka	'vice'
t^{s}vet	t^{s}veta	'color'
prut	pruda	'pond'
soldat	soldata	'soldier'
zavot	zavoda	'factory'
xlep	xleba	'bread'
grip	griba	'mushroom'
trup	trupa	'corpse'

To give an explanation for the phonological processes at work in these data, we must take on the preliminary task of describing the morphology of noun declension, on the basis of the information we have available. While morphological analysis is not part of phonology per se, it is inescapable that a phonologist must do a morphological analysis of a language, in order to motivate phonological underlying forms.

In each of the examples above, the genitive form is nearly the same as the nominative, except that the genitive also has the vowel [a] which is the genitive singular suffix. We will therefore assume as our initial hypothesis that the bare root of the noun is used to form the nominative case, and the combination of a root plus the suffix *-a* forms the genitive. Nothing more needs to be said about examples such as *vagon ~ vagona, avtomobil^{y} ~ avtomobil^{y}a* or *večer ~ večera*, where, as it happens, the root ends with a sonorant consonant. The underlying forms of these noun stems are /vagon/, /avtomobil^{y}/ and /večer/, and these underlying forms are identical to the nominative form. With the addition of the genitive suffix *-a* this will also give the correct form of the genitive.

There are other stems where that portion of the word which corresponds to the root is the same: *karandaš ~ karandaša, golos ~ golosa, les ~ lesa, urok ~ uroka, porok ~ poroka, tˢvet ~ tˢveta, soldat ~ soldata* and *trup ~ trupa*. However, in some stems, there are differences in the final consonant of the consonant, depending on whether we are considering the nominative and the genitive. Thus, we find the differences *muš ~ muža, glas ~ glaza, porok ~ poroga, vrak ~ vraga, prut ~ pruda* and *xlep ~ xleba*. Such variation in the phonetic content of a morpheme (such as a root) are known as **alternations**. We can easily recognise the phonetic relation between the consonant found in the nominative and the consonant found in the genitive as involving voicing: the consonant found in the nominative is the voiceless counterpart of the consonant found in the genitive. Not all noun stems have such an alternation, as we can see by pairs such as *karandaš ~ karandaša*, *les ~ lesa*, *urok ~ uroka*, *soldat ~ soldata* and *trup ~ trupa*. We have now identified a phonological problem to be solved: why does the final consonant of some stems alternate in voicing? And why do we find this alternation with some stems, but not others?

The next two steps in the analysis are intimately connected; we must devise a rule to explain the alternations in voicing, and we must set up appropriate underlying representations for these nouns. In order to determine the correct underlying forms, we will consider two competing hypotheses regarding the underlying form, and in comparing the predictions of those two hypotheses, we will see that one of those hypotheses is clearly wrong.

Suppose, first, that we decide that the form of the noun stem which we see in the nominative is also the underlying form. Such an assumption is reasonable (it is, also, not automatically correct), since the nominative is grammatically speaking a more 'basic' form of a noun. In that case, we would assume the underlying stems /glas/ 'eye', /golos/ 'voice', /ras/ 'time' and /les/ 'forest'. The problem with this hypothesis is that we would have no way to explain the genitive forms *glaza*, *golosa*, *raza* and *lesa*: the combination of the assumed underlying roots plus the genitive suffix *-a* would give us **glasa*, *golosa*, **rasa* and *lesa*, so we would be right only about half the time. The important step here is that we test the hypothesis by combining the supposed root and the affix in a very literal-minded way, whereupon we discover that the predicted forms and the actual forms are different.

We could hypothesize that there is also a rule voicing consonants between vowels (a rule like one which we have previously seen in Kipsigis, Ch. 3):

(2) C → voiced / V ___ V

While applying this rule to the assumed underlying forms /glas-a/, /golos-a/, /ras-a/ and /les-a/ would give the correct form *glaza*, it would also give incorrect surface forms such as **goloza*, *raza* and **leza*. Thus, not only is our first hypothesis about underlying forms wrong, it also cannot be fixed by positing a rule of consonant voicing.

The student may be tempted to posit a rule that only applies in certain words, such as the words for "eye", "time" and so on, but not "voice", "forest" and so on. This misconstrues the nature of phonological rules, which are general principles that apply to all words of a particular class — most generally, these classes are defined in terms of phonological properties, such as "obstruent", "in word-final position". Rules which are stated as "only applying in the following words" are almost always wrong, and the student should reconsider the question of what the underlying form is, rather than contemplating a rule that only applies to some stipulated list of words.

What is wrong with our "nominate is underlying" analysis is that this fundamental assumption is wrong. In the nominative form of the noun, there is a consistent phonetic property, namely that any root-final obstruent (which is therefore word-final) is always voiceless, whereas in the genitive form there is no such consistency. If one looks at the genitive column, the last consonant of the root portion of the word may be either voiced or a voiceless. The reason why we had to reject the idea that the nominative is the underlying form is that we could not come up with a consistent rule to predict when certain consonants become voiced.

We now consider a second hypothesis, since we were unable to predict the form of certain nouns in the genitive. Instead, we will set up underlying representations which make a distinction between some stems which have a voiced obstruent in the genitive versus those which have a voiceless obstruent. We will therefore assuming the following underlying roots.

(3)

Final voiced obstruent		*Final voiceless obstruent*	
/muž/	'husband'	/karandaš/	'pencil'
/glaz/	'eye'	/golos/	'voice'
/raz/	'time'	/les/	'forest'
/porog/	'threshold'	/porok/	'vice'
/vrag/	'enemy'	/urok/	'lesson'
/prud/	'pond'	/tsvet/	'color'
/zavod/	'factory'	/soldat/	'soldier'
/grib/	'mushroom'	/trup/	'corpse'
/xleb/	'bread'		

Under this hypothesis, the genitive form can be derived trivially. The genitive form is the stem hypothesized in (3) followed by the suffix -*a*. No rule is required to derive voiced versus voiceless consonants in the genitive. That issue has been resolved by our choice of underlying representations where some stems end in voiced consonants and others end in voiceless consonants. By our hypothesis, the nominative form is simply the underlying form of the noun stem, with no suffix.

However, a phonological rule must apply to the nominative form, in order to derive the correct phonetic output. We have noted that no word in Russian ends

phonetically with a voiced obstruent. This regular fact allows us to posit the following rule, which devoices any word-final obstruent.

(4) *Final devoicing*
obstruent → voiceless / ___ #

By this rule, an obstruent is devoiced at the end of the word. As this example has shown, an important first step in doing a phonological analysis for phenomena such as word-final devoicing in Russian is to establish the correct underlying representations, which encode unpredictable information.

The information whether a consonant is voiced cannot be predicted in English ([dɛd] 'dead', [tɛd] 'Ted', [dɛt] 'debt]), and thus must be part of the underlying form. In Russian, since one cannot predict by any rule whether a root ends in a voiced or a voiceless consonant in the genitive, that information must be part of the underlying form of the root. Moreover, that information cannot be determined by looking only at the surface form of the word which undergoes the rule in question — the nominative, in this case — but rather must be discovered by comparing the nominative form of the noun with the genitive form.

2. What Is an Underlying Form?

It is important to understand what underlying forms are, and what they are not. The nature of underlying forms can be best appreciated in the context of the overall organization of a grammar, and how a given word is generated in a sentence. The structure of a grammar can be represented in terms of the standard block model.

(5) *Syntax* → *Morphology* → *Phonology* → *Phonetics*

This model implies that the output of one component forms the input to the next component, so the phonological component starts with whatever the morphological component gives it, and applies its own rules (which are then subject to principles of physical interpretation in the phonetic component). The output from the morphology, which is the input to the phonology, is definitionally the underlying form, so we need to know a little bit about what the morphological component does, to understand what is presented to the phonology.

The function of the morphological component is to assemble words, in the sense of stating how roots and affixes combine to form a particular word. Thus the morphological component is responsible for combining a noun root [dag] and a plural affix [z] in English to give the word *dog-s* (i.e. /dag-z/), or in Russian the morphology combines a noun root [vagon] with an inflectional ending [a] according to rules of inflection for Russian, to give the genitive word *vagon-a*. Each morpheme is assumed to have a single constant phonetically-defined shape coming

out of the morphology (there are a few exceptions such as the fact that the third person singular form of the verb 'be' in English is [ɪz] and the first person singular of that verb is [æm]). The phonetic realization of any morpheme is subject to rules of phonology, so while the morphology provides the plural morpheme *z* (spelled <s>), the application of phonological rules will make that that morpheme being pronounced as [s] as in *cats* or [ɨz] as in *bushes*.

It is very important to understand that the grammar does not formally derive one word from another:[1] rather, one word derives from a given abstract root plus whatever affixes are relevant, and a related word derives by adding a different set of affixes to the same abstract root. Accordingly, the plural of a noun in English does not derive from the singular, rather, both the singular *and* the plural forms derive from a common root: no suffix is added to the root in the singular, and the suffix /z/ is added to the root in the plural. The Russian genitive [vagona] also does not derive from the nominative, nor does the nominative derive from the genitive. Rather, both derive from the root /vagon/, where the nominative adds no affix and the genitive adds the affix -*a*.

The underlying form of a word is whatever comes out of the morphology and is fed into the phonology, before any phonological rules have applied. The underlying form of the word [kæts] is /kæt-z/, since that is what results in the morphology by applying the rule that combines a noun root such as 'cat' with the plural suffix. The underlying form of the plural word [kæts] is *not* /kæt/, because the plural word has to have the plural morpheme. However, /kæt/ *is* the underlying form of the singular word [kæt]. There is no phonological rule which inserts *z* or *s* in order to form a plural. The principles for combining roots and affixes are not part of the phonology, and thus there is no need to include rules such as 'insert [z] in the plural'. Be explicit about what you assume about morphology in a language, i.e. that there is a plural suffix -*z* in English or a genitive suffix -*a* in Russian. As for the mechanics of phonological analysis, you should assume, for example, that the plural suffix is already present in the underlying form, and therefore do not write a rule to insert the plural suffix since that rule is part of morphology. A phonological analysis states the underlying forms of morphemes, and describes changes in the phonological shape of the root or suffix.

We have concuded that the underlying form of the Russian word [prut] 'pond' is /prud/. In arriving at that conclusion, we saw how important it is to distinguish the phonological concept of an underlying form from the morphological concept 'basic form', where the singular form, or an uninflected nominative form would be the morphological 'basic form'. An underlying form is a strictly phonological concept and is not necessarily equivalent to an actually pronounced word (even disregarding the fundamental fact that underlying forms are discrete sym-

[1] Some languages seem to have exceptional morphological processes, which we will not be discussing here, that derive one word from another.

bolic representations whereas actually pronounced words are acoustic waveforms). It is a representation that is the foundation for explaininf the variety of actual pronounciations found in the morpheme, as determined by phonological context.

The morphologically basic form of Russian "pond" is the unmarked nominative, [prut], composed of just the root with no inflectional ending. In contrast, the phonological underlying form of "pond" is /prud/, for as we have seen, if we assume the underlying form to be */prut/, we cannot predict the genitive [pruda]. The word *[prud], with a voiced consonant at the end of the word, does not appear as such in the language, and thus the supposition that the underlying form is /prud/ is an abstraction, given that [prud] by itself is never found in the language — it must be inferred, in order to explain the actual data. The basis for that inference is the genitive form [pruda], which actually contains the hypothesized underlying form as a subpart. It is important to understand, however, that the underlying form of a root may not actually be directly attested in this way in any single word, and we will discuss this point in section 6.

3. Finding the Underlying Form

A similar problem arises in explaining the partitive and nominative forms of nouns in Finnish. The first step in understanding the phonological alternation seen here is to do a standard preliminary morphological analysis of the data, which involves identifying which parts of a word correlate with each aspect of word structure (such as root meaning or grammatical case). The following examples illustrate that the nominative singular suffix is ∅ (i.e. there is no overt suffix in the nominative singular) and the partitive singular suffix is -*æ*, which alternates with -*a* if there is a back vowel somewhere before it in the word (we will not be concerned with that vowel alternation in the partitive suffix).

(6)

	nominative sg.	*partitive sg.*	*gloss*
a.	aamu	aamua	morning
	hopea	hopeaa	silver
	katto	kattoa	roof
	kello	kelloa	clock
	kirya	kiryaa	book
	külmæ	külmææ	cold
	koulu	koulua	school
	lintu	lintua	bird
	hüllü	hüllüæ	shelf
	kömpelö	kömpelöæ	clumsy
	nækö	næköæ	appearance

b.	yoki	yokea	river
	kivi	kiveæ	stone
	muuri	muuria	wall
	naapuri	naapuria	neighbor
	nimi	nimeæ	name
	kaappi	kaappia	chest of drawers
	kaikki	kaikkea	all
	kiirehti	kiirehtiæ	hurry
	lehti	lehteæ	leaf
	mæki	mækeæ	hill
	ovi	ovea	door
	posti	postia	mail
	tukki	tukkia	log
	æiti	æitiæ	mother
	englanti	englantia	England
	yærvi	yærveæ	lake
	koski	koskea	waterfall
	reki	rekeæ	sledge
	væki	vækeæ	people

We might assume that the underlying form of the root is the same as the nominative (which has no suffix). The problem which these data pose is that in some nouns, the partitive appears to be simply the nominative plus the suffix *-ä* ~ *-a* (for example *muuri* ~ *muuria*), but for other nouns the final vowel alternates, with [i] in the nominative and [e] in the partitive (e.g. *yoki* ~ *yokea*). It is obvious that the nature of the following vowel does not explain this alternation, since the same surface quality suffix vowel can appear after either *e* or *i* — cf. *yok**e**a*, *nim**e**æ* where [e] appears before both [a] and [æ], versus *muur**i**a*, *kiireht**i**æ* where [i] appears before these same vowels. Nor can the preceding consonant be called upon to predict what vowel will appear in the partitive, as shown by pairs such as *tu**kk**ia*, *kai**kk**ea* versus *leh**t**eæ, æ**i**t**i**æ.*

This is an area where there is (potentially) a difference between language learning pedagogy and a formal linguistic analysis. Faced with the problem of learning the inflectional distinction *muuri* ~ *muuria* versus *yoki* ~ *yokea*, a second-language class on Finnish might simply have the student memorize a list of words like *yoki* ~ *yokea* where the vowel changes in the inflectional paradigm. From the point of view of linguistic analysis this is the wrong way to look at the question, since it implies that this is not a rule-governed property of the language. However, second language learning is not the same as linguistic analysis: a class in foreign language instruction has a different goal from a class in analysis, and some students in a language class may receive greater practical benefit from just memorizing a list of words. Thus it is important to distinguish the teaching method where

one learns arbitrary lists, and a theoretically-based analysis. One simply cannot predict what vowel will appear in the partitive form if you only consider the pronunciation of the nominative. This means: nominative forms are not the same as underlying forms (something that we also know ronm the previous Russian example). The underlying representation must in some way contain that information which determines whether there will be a vowel alternation in a given word.

In looking for the phonological basis for this vowel alternation, it is important to realize that the alternation in stem-final vowels is not chaotic, for we find precisely two possibilities, either *i* in the nominative paired with *i* in the partitive, or *i* in the nominative paired with *e* in the partitive — never, for example, *i* paired with *u* or *i* paired with *o*. Moreover, only the vowel *i* enters into such a vowel alternation in Finnish, so there are no nouns with *o* in the nominative which is replaced by *u* in the partitive, nor is *u* in the nominative ever replaced by *o* or any other vowel in the partitive. One final fact about the data in (6) suggests exactly how the right underlying representations that can explain this alternation: of the eight vowels of Finnish (*i, ü*, *e, ö, æ, u, o, a*), all of them appear at the end of the word except the vowel *e*. Now, since the stem of 'name', which appears as *nimi* in the nominative actually appears on the surface as *nime-* in the partitive, it is not at all unreasonable to assume that the underlying form of the stem 'name' is in fact /nime/. It would be a bit bizarre to assume an underlying form such as /nima/, since the vowel [a] never appears in that position in any form of this word: the most natural assumption to make is that the underlying form of a morpheme is composed of actually segments found in some surface manifestation of the morpheme. On the other hand, the stem of 'wall' is pronounced *muuri* in both the nominative and the partitive, and therefore there is no reason to assume that it is underlyingly anything other than /muuri/.

This is a natural assumption but not an absolute rule, as we see in Ch. 10. Underlying forms can contain segments not found in any form of the word. Only when there is strong evidence for departing from this assumption are you justified in setting up underlying forms with such abstract elements.

We will then assume that the underlying vowel at the end of the stem is actually reflected by the partitive form, and thus we would assume underlying representations such as /yoke/, /nime/, /kive/, /lehte/, /ove/ and so on, as well as /muuri/, /naapuri/, /kaappi/, /tukki/ and so on. The underlying form of partitive [yoke-a] would thus be /yoke-a/, that is, no rule at all is required to explain the partitive. Instead, a rule is needed to explain the surface form of the nominative [yoki], which derives from /yoke/. A very simple neutralizing rule can explain the surface form of the nominative: underlying word-final *e* is raised to *i*.

(7) *Final vowel raising*
e → i / ___ #

This rule is neutralizing since the distinction between /i/ and /e/ is neutralised by applying this rule: an underlying /e/ becomes phonetic [i].

Apart from illustrating how important correct underlying forms are, these two examples have also shown that it is dangerous, and incorrect in these two cases, to assume that the 'most basic' form of a word according to morphological

criteria is also the underlying form of the word. To reiterate: the underlying form of a morpheme is a hypothesis set forth by the analyst, a claim that by assuming such-and-such an underlying form, plus some simple set of rules (which need to be discovered by the analyst), the observed variation in the shape of morphemes can be explained.

Kikerewe. To better understand the reasoning that leads to correct underlying forms, we investigate other examples. Consider the following data from Kikerewe.

(8)

infinitive	*1s habitual*	*3s habitual*	*imperative*	*gloss*
kupaamba	mpaamba	apaamba	paamba	adorn
kupaaŋga	mpaaŋga	apaaŋga	paaŋga	line up
kupima	mpima	apima	pima	measure
kupuupa	mpuupa	apuupa	puupa	be light
kupekeča	mpekeča	apekeča	pekeča	make fire with stick
kupiinda	mpiinda	apiinda	piinda	be bent
kuhiiga	mpiiga	ahiiga	hiiga	hunt
kuheeka	mpeeka	aheeka	heeka	carry
kuhaaŋga	mpaaŋga	ahaaŋga	haaŋga	create
kuheeba	mpeeba	aheeba	heeba	guide
kuhiima	mpiima	ahiima	hiima	gasp
kuhuuha	mpuuha	ahuuha	huuha	breath into

We notice that every infinitive begins with *ku*-, which we surmise is the prefix for the infinitive; the 3s. habitual form has the prefix *a*-, and the 1s. habitual has the prefix *m*-; the imperative involves no prefix. In addition to segmental prefixes, there is a change in the first consonant of the stem in some verbs, in some contexts. The initial consonant of the verb meaning 'guide' alternates between [h] and [p], with [p] appearing in the 1s. habitual after [m] and [h] appearing elsewhere. Since this stem appears in two surface variants, [heeba] and [peeba], two plausible hypotheses are immediately possible: the stem is underlying /peeba/, or the stem is underlying /heeba/. If we assume that the stem is underlying /heeba/, we require a rule to explain the divergence between the predicted form of the 1s. habitual form — we would expect *[mheeba], *[mhiima] etc. — and the actual form of the verb, [mpeeba], [mpiima] and so on. Since in fact we do not see the sequence /mh/ anywhere in the data, we might assume the following neutralizing rule.

We only have direct evidence for the change after *m*, so it would be possible to restrict our rule to the more specific context "after m". But this would run counter to basic assumptions of science, that we seek the most general explanations possible, not the most restricted

(9) *Post-nasal hardening*
h → p / nasal ___

If, on the other hand, we assume that the root 'guide' is underlyingly /peeba/, we would need a rule which changes /p/ into [h] when not preceded by a nasal — in other words, when preceded by a vowel or by nothing. There is no

single property which groups together word initial position and vowels. Thus, the supposed rule changing /p/ to [h] would have to be a disjunction of two separate environments.

(10) $$p \rightarrow h \ / \ \begin{Bmatrix} \# \\ V \end{Bmatrix} \_\_$$

This suggests that rule (10) is wrong.

More important than the greater complexity of the rule entailed by assuming that 'guide' is underlying /peeba/, that is simply wrong, empirically. Rule (10) implicitly claims that /p/ should always become [h] word initially or after a vowel, but this claim is falsified by forms such as *kupaamba, apaamba, paamba* 'adorn' and *kupaaŋga, apaaŋga, paaŋga* 'line up'. If one assumes that all of these stems uniformly begin with /p/, then one cannot predict whether the imperative or infinitive has [h] (*kuhaaŋga*) or [p] (*kupaaŋga*). On the other hand, if one assumes an underlying contrast between initial /h/ and initial /p/ — i.e. *haaŋga* 'create', *paaŋga* 'arrange' — then one can correctly distinguish those stems which begin with /h/ from those which begin with /p/ when no nasal precedes, as well as correctly neutralizing that distinction just in case the stem is preceded by a nasal (*mpaaŋga* 'I create'; 'I arrange').

English plurals. A further illustration of how to determine the correct underlying representation comes from English. As the following examples illustrate, the surface form of the plural suffix varies between [s] and [z] (as well as [ɨz], to be discussed later).

(11)

kæps	'caps'	kæbz	'cabs'	klæmz	'clams'
kæts	'cats'	kædz	'cads'	kænz	'cans'
kaks	'cocks'	kagz	'cogs'	karz	'cars'
pruwfs	'proofs'	hʊvz	'hooves'	gəlz	'gulls'
		fliyz	'fleas'		
		plæwz	'plows'		
		pyr̩ez	'purees'		

The generalization regarding distribution is straightforward: [s] appears after a voiceless segment, and [z] appears after a voiced one (be it an obstruent, a liquid, nasal or a vowel).

This same alternation can be found in the suffix marking the 3rd singular present tense form of verbs.

(12)	slæps	'slaps'	stæbz	'stabs'	slæmz	'slams'
	hɪts	'hits'	haydz	'hides'	kænz	'cans'
	powks	'pokes'	dɪgz	'digs'	hæŋz	'hangs'
	læfs	'laughs'	θrayvz	'thrives'	hiylz	'heals'
	pɪθs	'piths'	beyðz	'bathes'	hɪrz	'hears'
			flayz	'flies'	viytowz	'vetos'

If we suppose that the underlying form of the affixes for noun plural and 3rd singular present verbs are /z/, then we would assume the following rule to derive the phonetic variant [s].

(13) obstruent → voiceless / voiceless ___

On the other hand, if we were to assume that these suffixes are underlyingly /s/, we would assume the following rule.

(14) obstruent → voiced / voiced ___

In terms of the simplicity and generality of these two rules, the analyses are comparable. Both fomulations require the same number of phonetic specifications to state the rule, and both formulations apply to general and phonetically natural classes. However, the two analyses differ quite significantly in terms of their overall predictions for English. The implicit prediction of the first rule (13) is that there should be no voiced obstruents after voiceless segments in English, since that rule would devoice all such obstruents. This generalization seems to be correct: there are no words like *[yəkd], *[pɪvs], *[sdap]. The implicit prediction of the second rule (14) is different: that rule implies that there should be no voiceless segments after any voiced segments. This is manifestly incorrect, as shown by the existence of words such as [hɪs] 'hiss', [pæθ] 'path', [dæns] 'dance', [fals] 'false'. We prefer a hypothesis which makes the correct prediction about the phonetic structure of the language as a whole, and thus we select the underlying form /z/ and a rule devoicing obstruents after voiceless segments. Looking for such asymmetries plays an important role in determining which of two hypotheses is the correct one.

The alternation *z* ~ *s* is not limited to the two affixes -*z* 'plural' and -*z* '3 sg. present tense'. The rule of devoicing can also be seen applying to the possessive suffix -*z*.

(15)	*Noun*	*Noun+poss.*	
	kæt	kæts	"cat"
	sləg	sləgz	"slug"
	klæm	klæmz	"clam"
	snow	snowz	"snow"

Moreover, certain auxiliary verbs such as *has* [hæz] and *is* [ɪs] undergo a reduction in casual speech, so that they appear simply as [s] or [z], the choice between these two being determined by the devoicing rule which we have motivated.

(16)	*Noun + has*	*reduced*	*Noun + is*	*reduced*	
	ǰæk hæz iyʔn̩	ǰæks iyʔn̩	ǰæk ɪz iyɒɪŋ	ǰæks iyɒɪŋ	"Jack"
	pæt hæz iyʔn̩	pæts iyʔn̩	pæt ɪz iyɒɪŋ	pæts iyɒɪŋ	"Pat"
	ǰɛn hæz iyʔn̩	ǰɛnz iyʔn̩	ǰɛn ɪz iyɒɪŋ	ǰɛnz iyɒɪŋ	"Jen"
	bab hæz iyʔn̩	babz iyʔn̩	bab ɪz iyɒɪŋ	babz iyɒɪŋ	"Bob"
	ǰow hæz iyʔn̩	ǰowz iyʔn̩	ǰow ɪz iyɒɪŋ	ǰowz iyɒɪŋ	"Joe"

The devoicing rule (13) automatically explains the alternation in the surface shape of the consonant here as well.

Jita tone. It is important to look for correlations which may lead to causal explanations, in analyzing data. Consider the following data from Jita, concentrating on the tones of morphemes (H tone is marked with acute accent, L toned syllables are unmarked).

(17)					
	a.	okuβuma	"to hit"	okusiβa	"to block"
		okuβumira	"to hit for"	okusiβira	"to block for"
		okuβumana	"to hit e.o."	okusiβana	"to block e. o."
		okuβumirana	"to hit for e.o."	okusiβirana	"to block for e.o."
	b.	okulúma	"to bite"	okukúβa	"to fold"
		okulumíra	"to bite for"	okukuβíra	"to fold for"
		okulumána	"to bite e.o."	okukuβána	"to fold e.o"
		okulumírana	"to bite for e.o."	okukuβírana	"to fold for e.o"

We can conclude that there is a prefix *oku-* perhaps marking the infinitive, a suffix *-a* appearing at the end of every verb, and two suffixes *-ir-* "for" and *-an-* "each other". There are also root morphemes: *-βum-* "hit", *-siβ-* "block", as well as *-lúm-* "bite" and *-kúβ-* "fold". We decide that "bite" and "fold" underlyingly have H tones in part based on the fact that there actually is a H tone on the vowels of these roots in the simplest verb forms.

In addition, we observe that the suffixes *-ir-* and *-an-* have H tone when they come immediately after these verb roots. The suffixes do not have H tone after the first set of roots: appearance of H on the suffix is correlated with which morpheme immediately precedes the suffix. Since this unpredictable property is correlated with the preceding root morpheme, it must therefore be an aspect of the underlying form of the preceding morpheme.

We thus explain the H tone on these suffix morphemes by positing that [oku-lum-án-a] derives from underlying /oku-lúm-an-a/, by applying a rule of tone

shift which shifts a H tone rightward to the following syllable, as long as the syllable is not word-final. Because of the restriction that H does not shift to a final syllable, the underlying H surfaces unchanged in [okulúma].

Now consider the following data.

(18)	okumuβúma	"to hit him/her"	okumusíβa	"to block him/her"
	okumuβúmira	"to hit for him/her"	okumusíβira	"to block for him/her"
	okučiβúma	"to hit it"	okučisíβa	"to block it"
	okučiβúmira	"to hit for it"	okučisíβira	"to block for it"

When the L-toned roots of (17a) stand after the object prefixes -*mu*- "him/her" and -*či*- "it", they have a H tone at the beginning of the root. Again, since the presence of the H is correlated unpredictably with the prefixes -*mu*- and -*či*-, we hypothesize that the tones are *part* of the underlying representation of the prefixes — the prefixes are /mú/ and /čí/, and the H tone shifts to the right by the tone shift rule which we have already posited.

4. Practice at problem solving

You should now be able to apply this reasoning to data which pose analogous problems; a series of examples are given in this section for practice.

Chamorro vowel alternations. There are alternations in the quality of vowels in initial syllables in some contexts seen in the following data from Chamorro.

(19)	gwíhən	'fish'	i gwíhən	'the fish'
	gúməʔ	'house'	i gíməʔ	'the house'
	cúpa	'cigarettes'	i cípa	'the cigarettes'
	fínoʔ	'talk'	mi fínoʔ	'lots of talk'
	túnuʔ	'to know'	en tínuʔ	'you know'
	cúgoʔ	'juice'	mi cígoʔ	'lots of juice'
	sóŋsuŋ	'village'	i séŋsuŋ	'the village'
	húluʔ	'up'	sæn hílu ʔ	'upward'
	pécu	'chest'	i pécu	'the chest'
	tómu	'knee'	i tému	'the knee'
	ótdut	'ant'	mi étdut	'lots of ants'
	óksuʔ	'hill'	gi éksuʔ	'at the hill'
	dáŋkulu	'big one'	i dǽŋkulu	'the big one'
	láhi	'male'	i lǽhi	'the male'
	lágu	'north'	sæn lǽgu	'toward north'
	pulónnun	'trigger fish'	i pulónnun	'the trigger fish'
	mundóŋgu	'cow's stomach'	i mundóŋgu	'the cow's stomach'
	putamonéda	'wallet'	i putamonéda	'the wallet'

What underlying representations, and what rule or rules, are required to account for these data? In answering this question, you should consider two hypotheses which differ especially about what form is taken to be underlying — what are the two most obvious ways of treating these alternations? One of these hypotheses is clearly wrong; the other is the correct hypothesis.

Korean. Now consider the following data from Korean. The first column, that of the infinitive, seems to involve a vowel suffix. One reason to think that there is an infinitive suffix is that every infinitive ends either in the vowel *a* or in *ə* (the choice between *a* versus *ə* is based of the vowel which precedes that suffix, /a/ or /o/ versus other vowels, and can be ignored here). A second reason for coming to this conclusion comes from comparing the infinitive and the plain present forms. Comparing *ana* and *annɨnta*, or *kama* and *kamnɨnta*, we can see that for each verb, the portions common to both the infinitive and the plain present are respectively *an-* and *kam-*. From this we deduce that there must be a suffix, either *-a* or *-ə*, which marks the infinitive, and another suffix *-nɨnta* which marks the plain present.

(20)

Infinitive	*Plain Present*	
ana	annɨnta	'hug'
kama	kamnɨnta	'wind'
sinə	sinnɨnta	'wear shoes'
t'atɨmə	t'atɨmnɨnta	'trim'
nəmə	nəmnɨnta	'overflow'
nama	namnɨnta	'remain'
$č^h$ama	$č^h$amnɨnta	'endure'
ipə	imnɨnta	'wear'
kupə	kumnɨnta	'bend'
čəpə	čəmnɨnta	'fold'
tatə	tannɨnta	'close'
put^hə	punnɨnta	'adhere'
$čoč^h$a	čonnɨnta	'follow'
məkə	məŋnɨnta	'eat'
sək'ə	səŋnɨnta	'mix'
tak'a	taŋnɨnta	'polish'
čukə	čuŋnɨnta	'die'
ikə	iŋnɨnta	'ripen'

What is the underlying form of these verb stems, and what phonological rule or rules are required to account for the variations that are seen in the surface shape of the various stems?

Koasati. What is the underlying form of the 1 sg. possessive prefix in Koasati, and what phonological rule applies in these examples?

(21)

noun	*my N*	
apahčá	amapahčá	‘shadow’
asikčí	amasikčí	‘muscle’
ilkanó	amilkanó	‘right side’
ifá	amifá	‘dog’
a:pó	ama:pó	‘grandmother’
iskí	amiskí	‘mother’
pačokkó:ka	ampačokkó:ka	‘chair’
towá	antowá	‘onion’
kastó	aŋkastó	‘flea’
bayá:na	ambayá:na	‘stomach’
tá:ta	antá:ta	‘father’
čofkoní	añčofkoní	‘bone’
kitɨłká	aŋkitɨłká	‘hair bangs’
toní	antoní	‘hip’

Kimatuumbi. What phonological rules pertaining to consonants operate in the following examples from Kimatuumbi. What are the underlying forms of the stems for ‘rope’, ‘palm’, ‘tongue’, ‘piece of wood’, ‘pole’ and ‘covered’? Ignore tonal changes.

(22)

Singular	*Plural*	*Gloss*
lugói	ŋgói	‘rope’
lugolóká	ŋgolóká	‘straight’
lubáu	mbáu	‘rib’
lubágalo	mbagálo	‘lath’
lŭjiíŋgyá	ñ̃jiíŋgyá	‘entered’
lulaála	ndaála	‘pepper’
lulímí	ndími	‘tongue’
lulɪndíɪlá	ndɪndíɪlá	‘guarded’
lupaláaí	mbaláaí	‘bald head’
lupaálá	mbaálá	‘wanted’
lutéelá	ndeelá	‘piece of wood’
lukíligo	ŋgilígo	‘place for initiates’
lukíli	ŋgíli	‘palm’
luyímá	ñ̃jíma	‘pole’
luyóka	ñ̃jóka	‘stomach worm’
luyúsí	ñ̃júsi	‘bee’
luyúwé	ñ̃júwe	‘pumpkin plant’
luwɪkílyá	ŋg^{w}ɪkílyá	‘covered’

A certain degree of uncertainty regarding the exact underlying form of the plural prefix is expected. However, the underlying form of the stem should be clear, and should be the focus of your analysis.

5. Underlying forms and Sentence-Level Phonology

In the examples which we have considered so far, we have been comparing morphologically related words, such as a nominative and a genitive, and we have seen that an underlying distinction may be preserved in one word in a particular inflected form (because in that inflected form the conditions for applying the phonological rule are not satisfied), but the difference is neutralised in a related word where the conditions for the rule are present. We now consider two additional cases where underlying distinctions are neutralised depending on context, and the neutralization takes place within one and the same word, depending on where the word appears in a sentence. What this shows is that phonology is not just about variations in pronunciation between words, but also includes variations in the pronunciation of a word in different sentential contexts.

5.1. Korean final C's

The first case is a rule of Korean that nasalizes stops before nasal consonants (a rule that we have seen operating within words in the preceding section). The first set of examples shows the word 'rice' when said alone, or when it is followed by various words which begin with oral consonants and vowels. In these data, the last consonant of the word 'rice' is pronounced as [p]. In the second set of examples, the word which follows 'rice' begins with a nasal, and in that case the final consonant of 'rice' is pronounced as [m].

(23)	a.	pa**p**	'rice'
		pa**p** anməkət'a [rice didn't eat]	'didn't eat rice'
		pa**p** winmoge tuət'a rice on-upper-floor put	'put rice on the upper floor'
		pa**p** saməkət'a rice ate-at-store	'ate rice at a store'
		pa**p** totuki humčʰəgat'a rice thief (subj) stole	'a thief stole rice'
	b.	pa**m** mani məkəla rice a lot eat	'eat rice a lot'

pa**m** mək-imyən rice eat-if	'if eats rice'
pa**m** nəmu masik'e məkət'a rice very deliciously ate	'I enjoyed rice quite a lot'
pa**m** nək^{h}o rice add	'add rice'

Compare those examples with the following examples with the word 'chestnut'.

(24)	a.	pa**m**	'chestnut'
		pa**m** anməkət'a [chestnut didn't eat]	'didn't eat chestnut'
		pa**m** winmoge tuət'a chestnut on-upper-floor put	'put chestnut on the upper floor'
		pa**m** saməkət'a chestnut ate-at-store	'ate chestnut at a store'
		pa**m** totuki humč^{h}əgat'a chestnut thief (subj) stole	'a thief stole chestnut'
	b.	pa**m** mani məkəla chestnut a lot eat	'eat chestnut a lot'
		pa**m** mək-imyən chestnut eat-if	'if eats chestnut'
		pa**m** nəmu masik'e məkət'a chestnut very deliciously ate	'I enjoyed chestnut quite a lot'
		pa**m** nək^{h}o chestnut add	'add chestnut'

In fact the (b) phrases above are actually ambiguous as to whether the word being pronounces means 'chestnut' or 'rice'.

The last consonant of the word 'chestnut' is always [m], so we would presume that the underlying form of that word is /pam/. Since 'rice' varies between [pap] and [pam], and since we know that the underlying form cannot be /pam/ (this is the underlying form of 'chestnut', and 'chestnut' cannot have the same underlying form as 'rice' since they do not behave the same), we conclude that the under-

lying form of 'rice' is /pap/, and that a nasalization rule changes /p/ (in fact, all stops) to nasals before a nasal. Whether a word undergoes that rule depends on what follows the final consonant. One and the same word can be pronounced differently depending on the properties of the phrase in which it appears.

5.2. Kimatuumbi tone

In the Korean case which we just considered, it happens that the underlying forms of the word is the same as the way the word is pronounced when it is said alone. This situation does not hold in Kimatuumbi, where one has to know how a word is pronounced when it is *not* at the end of an utterance, in order to determine the underlying form of the word. The words in (25) have a H tone (marked with an acute accent) on the second vowel from the beginning of the word when said alone. When another word follows, they seem to lose that H tone.

(25)	kiwíkɩlyo	'cover'	ŋga kiwɩkɩlyo lí	'it isn't a cover'
	lubágalo	'lath'	ŋga lubagalo lí	'it isn't a lath'
	mikóta	'sugar canes'	ŋga mikota lí	'it isn't sugar canes'
	ŋguúŋguni	'bedbug'	ŋga ŋguuŋguni lí	'it isn't a bedbug'
	lukólogo	'brewery'	ŋga lukologo lí	'it isn't a brewery'
	mabáando	'thighs'	ŋga mabaando lí	'it isn't thighs'
	kikóloombe	'shell'	ŋga kikoloombe lí	'it isn't a shell'
	lipítanʊʊŋgʊ	'rainbow'	ŋga lipɩtanʊʊŋgʊ lí	'it isn't a rainbow'

In contrast, the words of (26), which also have a H tone on the second vowel from the beginning of the word when the word is said alone, keep their H tone when another word follows.

(26)	lukóŋgobe	'wood'	ŋga lukóŋgobe lí	'it's not wood'
	kitúkʊtʊkʊ	'quelea bird'	ŋga kitúkʊtʊkʊ lí	'it's not a quelea'
	diíwai	'wine'	ŋga diíwai lí	'it's not wine'
	lukóoŋgono	'chicken leg'	ŋga lukóoŋgono lí	'it's not a leg'
	lukóoŋgowe	'marble'	ŋga lukóoŋgowe lí	'it's not marble'
	matógolo	'waterbucks'	ŋga matógolo lí	'it's not waterbucks'
	mivíriiŋgo	'circles'	ŋga mivíriiŋgo lí	'it's not circles'
	kiyógoyo	'bird (sp.)'	ŋga kiyógoyo lí	'it's not a bird'
	kikálaaŋgo	'pan'	ŋga kikálaaŋgo lí	'it's not a pan'

There are no words in Kimatuumbi which are toneless when said by themselves, thus **kitekelyo* said by itself is an unattested kind of word. There is a clear contrast in tonal behavior between the words in (25) where the presence of a H tone on the second vowel depends on whether the word is said alone or is followed by some word, and those in (26) where the second vowel always has a H. The so-

lution to this puzzle is that the words in (26) have an underlying H tone on their second vowel, and thus nothing happens to that tone; but the words in (25) have no underlying H, and instead get a H at the end of an utterance by a rule that assigns a H tone to the second vowel of a toneless word which comes at the end of an utterance. Thus in the case of Kimatuumbi tone, the contrast between underlyingly toneless words and words with underlying H is best revealed by looking at the word when it appears *not* by it self: it is the citation form of the word that undergoes the neutralization rule, which is the opposite of the situation we just encountered in Korean.

6. Underlying Forms and Multiple Columns in the Paradigm

The following data from Samoan illustrate the very important point that it is wrong to think of deriving underlying forms by chopping off affixes from some single column of data. In the first set of examples, our initial task is to deduce the underlying form of each of the verb roots and the affix for the perfective form.

(27)	*simple*	*perfective*	*gloss*
	olo	oloia	rub
	lafo	lafoia	cast
	aŋa	aŋaia	face
	usu	usuia	get up and go early
	tau	tauia	reach a destination
	taui	tauia	repay
	sa:ʔili	sa:ʔilia	look for
	vaŋai	vaŋaia	face each other
	paʔi	paʔia	touch
	naumati	naumatia	be waterless
	sa:uni	sa:unia	prepare
	seŋi	seŋia	be shy
	lele	lelea	fly
	suʔe	suʔea	uncover
	taʔe	taʔea	smash
	tafe	tafea	flow
	ta:upule	ta:upulea	confer
	palepale	palepalea	hold firm

Examples such as *oloia, aŋaia,* and *usuia* suggest that the perfective suffix is *-ia*, and the simple form of the verb reflects the underlying form of the root. Examples such as *seŋi ~ seŋia* or *lele ~ lelea* suggest a phonological rule, since the combination of the presumed stems *ati* and *lele* with the perfective affix *-ia* would result in the incorrect forms **seŋiia, *leleia*. However, this problem can be corrected by positing a phonological rule which deletes a front vowel when it is preceded by a

front vowel. In the formalization of the rule, we say that the second front vowel is replaced by zero, which means that it is deleted.

(28) *Vowel-cluster reduction*
front vowel → ∅ / front vowel ___

An alternative hypothesis would be that [i] is inserted between a back vowel and the vowel [a], if we were to presume that the perfective suffix is underlyingly /a/.

(29) ∅ → i / back vowel ____ a

This would be quite unlikely on grounds of naturalness. It is common across languages for one of two adjacent vowels to be eliminated, and no language has been found with a rule that inserts a vowel between two other vowels. Additional data to be considered below will show that, in addition, this would just be plain wrong. We abandon the idea of inserting the vowel *i* and conclude that the underlying form of the perfective suffix must be *-ia*, hence there must be a rule deleting a front vowel after a front vowel. We would then conclude that the underlying representation of roots is best revealed in the simple verb, rather than the perfective, since the simple form of the verb shows whether the stems ends with /i/, a vowel which may be deleted in the perfective.

A rather different conclusion about arriving at underlying forms would have to be drawn from the following additional Samoan examples.

(30)

simple	*perfective*	*gloss*
tu:	tu:lia	stand
au	aulia	flow on
tau	taulia	cost
ma:tau	ma:taulia	observe
ʔalo	ʔalofia	avoid
ili	ilifia	blow
oso	osofia	jump
ulu	ulufia	enter
sao	saofia	collect
taŋo	taŋofia	take hold
asu	asuŋia	smoke
soa	soaŋia	have a friend
pole	poleŋia	be anxious
fesili	fesiliŋia	question
ifo	ifoŋia	bow down
ʔote	ʔoteŋia	scold
ula	ulaŋia	mock
tofu	tofuŋia	dive

milo	milosia	twist
laʔa	laʔasia	step
valu	valusia	scrape
taŋi	taŋisia	cry
vela	velasia	be cooked
motu	motusia	break
api	apitia	be lodged
mataʔu	mataʔutia	fear
eʔe	eʔetia	be raised
sau	sautia	fall
lava:	lava:tia	be able
oʔo	oʔotia	arrive
u:	u:tia	grip
ufi	ufitia	cover
puni	punitia	be blocked
tanu	tanumia	cover up
siʔo	siʔomia	be enclosed
moʔo	moʔomia	admire
ŋalo	ŋalomia	forget
tao	taomia	cover
sopo	sopoʔia	go across
fana	fanaʔia	shoot

Here, we see that the perfective form of the verb contains a consonant which is not present in the simple form. That consonant can be any one of *l, f, ŋ, s, t, m* or *ʔ*, given these data. An attempt to predict the nature of that consonant by an insertion rule proves fruitless. We could attempt to insert an appropriate consonant on the basis of the preceding vowel: but while *l* appears after *u*, so do *f* ([ulufia]), *ŋ* ([tofuŋia]) and *s* ([valusia]); and while *f* appears after *o*, so do *ŋ* ([ifoŋia]), *m* ([ŋalmoia]) and *s* ([milosia]). In short, it is simply impossible to predict from anything in the environment what the consonant of the perfective is going to be, if we start with the simple form as the underlying form: that consonant must be part of the underlying representation of the root. Thus the underlying forms of this second set of roots would be as follows.

(31)	tu:l	'stand'	aul	'flow on'
	taul	'cost'	ma:taul	'observe'
	ʔalof	'avoid'	ilif	'blow'
	osof	'jump'	uluf	'enter'
	saof	'collect'	taŋof	'take hold'
	asuŋ	'smoke'	soaŋ	'have a friend'
	poleŋ	'be anxious'	fesiliŋ	'question'
	ifoŋ	'bow down'	ʔoteŋ	'scold'

ulaŋ	‘mock’	tofuŋ	‘dive’
milos	‘twist’	laʔas	‘step’
valus	‘scrape’	taŋis	‘cry’
velas	‘be cooked’	motus	‘break’
apit	‘be lodged’	mataʔut	‘fear’
eʔet	‘be raised’	saut	‘fall’
lava:t	‘be able’	oʔot	‘arrive’
u:t	‘grip’	ufit	‘cover’
punit	‘be blocked’	tanum	‘cover up’
siʔom	‘be enclosed’	moʔom	‘admire’
ŋalom	‘forget’	taom	‘cover’
sopoʔ	‘go across’	fanaʔ	‘shoot’

The postulation of underlying consonants at the end of these roots entails the addition of a phonological rule, in order to account for the surface form of the simple verb where there is no final consonant. Noting that no word ends in a consonant phonetically in these examples, we can postulate the following rule of final consonant deletion.

(32) *Final consonant deletion*
$C \rightarrow \varnothing$ / ___ #

The underlying forms of these verbs can be heuristically derived by eliminating the perfective affix -*ia* from the perfective form. However, notice that we made a different heuristic assumption for the first group of roots, which underlying ended in a vowel. The point is that an underlying representation is whatever is required to correctly predict all of the surface variants of a given morpheme: it does not necessarily derive from any one column in a paradigm.

It is also important to understand the difference between saying that the underlying form *is* the simple form, or *is* the perfective form, and saying that we may best *learn* what the underlying form is by looking at the perfective, or simple for, or some other form. The underlying form of “stand” is /tu:l/. We learn that this is the underlying form by comparing the simple form [tu:] and the perfective [tu:lia] and understanding that the perfective form preserves important information about the underlying form that is lost ni the simple form. But the perfective form itself is [tu:lia] — this is not the underlying form.

Palauan. The language Palauan provides a second clear illustration of the point that one cannot always arrive at the correct underlying representation by looking at any single column in the paradigm. In this language, the underlying form of the word does not acually surface as such in any form of a word. Consider the following examples

(33)	*Present Middle*	*Future Innovative*	*Future Conservative*	*Meaning*
	mədáŋəb	dəŋəbáll	dəŋóbl	cover
	mətéʔəb	təʔəbáll	təʔíbl	pull out
	məŋétəm	ŋətəmáll	ŋətóml	lick
	mətábək	təbəkáll	təbákl	patch
	məʔárəm	ʔərəmáll	ʔəróml	taste
	məsésəb	səsəbáll	səsóbl	burn

The prefix for the present middle is apparently /mə/, the future suffix (found in the future conservative and the future innovative) is -*l*, and the innovative suffix is -*al*. The position of stress can be predicted by a simple rule: the final syllable is stressed if it ends in two consonants, otherwise the second to last (penultimate) syllable is stressed.

The fundamental problem of Palauan is how to predict vowel quality in the root. Notice that the root meaning 'cover' has three surface realizations: *dáŋəb*, *dəŋəb* and *dəŋób*. Looking at all of the data, we notice that the only full vowel in the word is the stressed vowel, which suggests that unstressed vowels are neutralized to schwa.

(34) *Unstressed vowel reduction*
unstressed V → ə

Note that this rule has no context: it does not matter what precedes or follows the unstressed vowel.

In order to predict that the stressed first vowel in 'cover' is [a], that choice of vowel must be part of the underlying representation, giving the partial solution /daŋVb/. In contrast, the first vowel of 'pull out' must be specified as [e], since that is the vowel which appears in this word when the first vowel is stressed, giving /teʔVb/. By the same reasoning, the second vowel of 'cover' must be [o], since that is the realization which the vowel has when it is stressed, and the second vowel of 'pull out' must be [i]. Thus, the underlying forms of the stems given above would be the following.

(35)				
	daŋob	'cover'	teʔib	'pull out'
	ŋetom	'lick'	tabak	'patch'
	ʔarom	'taste'	sesob	'burn'

The underlying form of a verb in Palauan is a rather abstract object, something which is never revealed in any single surface form. Rather, it must be deduced by looking at information which is manifested in a number of different morphologically related words derived from a single stem.

English. A similar example can be found in English, as the following examples show. We will ignore other alternations and focus only on vowel alternations. Thus for example, alternations such as the one between *k* and *s* can be ignored. Also, there are many idiolectal differences in the pronunciation of certain words such as 'economy', where some people pronounce the word as [iykánəmiy] and others pronounce it as [əkánəmiy]: we will only attempt to account for the latter pronunciation. Finally, the effect of low-level allophonic rules such as flapping and the derivation of syllabic sonorants are not indicated.

(36)	mánətown	'monotone'	mənátəniy	'monotony'
	tɛ́ləgræf	'telegraph'	təlɛ́grəfiy	'telegraphy'
	ɛ́pəgræf	'epigraph'	əpí̵grəfiy	'epigraphy'
	rɛ́lətɪv	'relative'	rəléyšən	'relation'
	əkánəmiy	'economy'	ɛ̀kənámɪk	'economic'
	díyfɛkt	'defect'	dəfɛ́ktɪv	'defective'
	dɛ́məkræt	'democrat'	dəmákrəsiy	'democracy'
	ítəliy	'Italy'	ətǽlyən	'Italian'
	hámənɪm	'homonym'	həmánəmiy	'homonymy'
	fənɛ́tɪks	'phonetics'	fòwnətíšən	'phonetician'
	stətístɪks	'statistics'	stæ̀təstíšən	'statistical'
	rəsíprəkəl	'reciprocal'	rɛ̀səprásətiy	'reciprocity'
	fənáləǰiy	'phonology'	fòwnəlá͡ǰəkəl	'phonological'
	lá͡ǰɪk	'logic'	ləǰíšən	'logician'
	sínənɪm	'synonym'	sənánəmiy	'synonnymy'
	ərístəkræt	'aristocrat'	ɛ̀rəstákrəsiy	'aristocracy'

As in Palauan, there is an alternation between stressed full vowel and unstressed schwa. We would therefore assume underlying stems with multiple full vowels, e.g. /manatown/, /tɛlɛgræf/, /ɛpɪgræf/, /dɛmakræt/, /fownalaǰ/ etc. However, not every unstressed vowel is reduced: cf. for example *rɛ́lətɪv, díyfɛkt, mánətown* where the unstressed vowel is in a closed syllable (followed by one or more consonants within that syllable).

Tonkawa: reaching the analysis step-by-step. Correct assumptions about underlying forms are crucial in understanding the variations found in the verb stem in Tonkawa, as the following examples will illustrate. The first step in accounting for these data is to provide a morphological analysis of the data, to determine what the morphemes are for the progressive, the present, the 1s object, and the 3p object, and to set forth hypotheses about the underlying forms of roots.

(37)	picnoʔ	'he cuts'	picnanoʔ	'he is cutting'
	wepcenoʔ	'he cuts them'	wepcenanoʔ	'he is cutting them'
	kepcenoʔ	'he cuts me'	kepcenanoʔ	'he is cutting me'
	notxoʔ	'he hoes'	notxonoʔ	'he is hoeing'
	wentoxoʔ	'he hoes them'	wentoxonoʔ	'he is hoeing them'
	kentoxoʔ	'he hoes me'	kentoxonoʔ	'he is hoeing me'
	netloʔ	'he licks'	netlenoʔ	'he is licking'
	wentaloʔ	'he licks them'	wentalenoʔ	'he is licking them'
	kentaloʔ	'he licks me'	kentalenoʔ	'he is licking me'
	naxcoʔ	'he makes fire'	naxcenoʔ	'he is making fire'
	wenxacoʔ	'he makes them fire'	wenxacenoʔ	'he is making them fire'
	kenxacoʔ	'he makes me fire'	kenxacenoʔ	'he is making me fire'
	yamxoʔ	'he paints a face'	yamxanoʔ	'he is painting a face'
	weymaxoʔ	'he paints their face'	weymaxanoʔ	'he is painting their face'
	keymaxoʔ	'he paints my face'	keymaxanoʔ	'he is painting my face'
	nawloʔ	'he spreads'	nawlenoʔ	'he is spreading'
	wenweloʔ	'he spreads them'	wenweleno?	'he is spreading them'
	kenweloʔ	'he spreads me'	kenweleno?	'he is spreading me'

It will be noticed that every word in this set ends with *oʔ*, and that all of these verb forms have a third person subject, which suggests that -*oʔ* is a suffix marking a third person subject. Comparing the habitual present forms in the first column with the corresponding present progressive form in the second column, it is also obvious that the present progressive is marked by a suffix, -*n*- or -V*n*-, ordered before the suffix -*oʔ*. Marking of an object on the verb is accomplished by a prefix, *we*- for 3 pl. object and *ke*- for 1 sg. object. What remains is the verb stem.

Two problems now remain: determining whether the suffix for the progressive is -*n*-, or is there a vowel which is part of the suffix; and, what is the underlying form of the verb root. To resolve the first question, we look just at the forms of the verb with no object:

(38)	picnoʔ	picn**a**noʔ
	notxoʔ	notx**o**noʔ
	netloʔ	netl**e**noʔ
	naxcoʔ	naxc**e**noʔ
	yamxoʔ	yamx**a**noʔ
	nawloʔ	nawl**e**noʔ

We might think that the vowel before -*n*- is part of the progressive suffix, but if it were part of that suffix, it should have a constant underlying form and all surface variants of that vowel should be derived by some simple rule(s). It is obvious from these examples that the vowel which appears before *n* does not have a single phonetic realization since in these examples it ranges over *a, o* and *e*, and that there is

no reasonable way to predict (e.g. from surrounding consonants or vowels) what vowel will appear before *n*. Since that information is unpredictable and is governed by which root appears before the suffix, the vowel must actually be part of the underlying form of the verb stem. Thus, we arrive at the following partial answer to the question about the underlying forms of the verb roots:

(39)	/picna/	'cut'
	/notxo/	'hoe'
	/netle/	'lick'
	/naxce/	'make a fire'
	/yamxa/	'paint a face'
	/nawle/	'spread'

The progressive form of the verb can be derived straightforwardly by adding the two affixes -*n*- and -*oʔ*. The habitual present involves the application of a further phonological process. Based on our hypotheses regarding the underlying forms of the verb stems, we predict the following underlying forms for the habitual forms.

(40)	predicted form	actual surface form	
	picnaoʔ	picnoʔ	'cut'
	notxooʔ	notxoʔ	'hoe'
	netleoʔ	netloʔ	'lick'
	naxceoʔ	naxcoʔ	'make a fire'
	yamxaoʔ	yamxoʔ	'paint a face'
	nawleoʔ	nawloʔ	'spread'

The underlying form is whatever is given by the morphological component, so in this case it would be the root plus progressive suffix, followed by the suffix -*oʔ*. Our initial hypothesis is that the underlying form should be identical to the surface form until we have evidence that phonological rules change the underlying forms in predictable ways. The difference between the predicted form and the actual surface realization of the verb is that the underlying form has a cluster of vowels which is not found in the surface form. The data do not provide any examples of surface vowel clusters, and this fact allows us to state a very simple rule accounting for the surface form: the first of two consecutive vowels is deleted.

(41) *Vowel cluster reduction*
$V \rightarrow \varnothing$ / ___ V

Now we turn to the alternations in the shape of the stem that arise between the plain forms of the verb and the verb with an object prefix. Verbs with the pre-

fix *ke-* behave exactly like verbs with the prefix *we-*. Disregarding the suffixes *-n-* and *-oʔ*, we arrive at the following surface variations in the shape of the stem.

(42)	stem without prefix	stem with CV prefix	
	picna	pcena	'cut'
	notxo	ntoxo	'hoe'
	netle	ntale	'lick'
	naxce	nxace	'make a fire'
	yamxa	ymaxa	'paint a face'
	nawle	nwele	'spread'

Notice that in the form which lacks a prefix there is a vowel between the first two consonants and none between the second and third consonants. By contrast, in the form with a CV prefix, there is no vowel between the first two consonants but there is a vowel between the second and third consonants. One way to solve this problem would be to assume that this vowel is epenthetic (inserted); the other is to assume that the vowel is part of the underlying vowel of the stem and is deleted in some phonological context. It is also obvious that just as there is no way to predict what vowel will appear between the first and second consonants, it is also impossible to predict what vowel will appear between the second and third consonants, and therefore the vowel cannot be epenthetic. In short, the underlying representation must contain unpredictable vowels after each consonant.

(43)	picena	'cut'
	notoxo	'hoe'
	netale	'lick'
	naxace	'make a fire'
	yamaxa	'paint a face'
	nawele	'spread'

The underlying forms of prefixed and unprefixed forms would thus be as follows (illustrating with the progressive form of the verb).

(44)	*unprefixed*	*prefixed*	
	/picenanoʔ/	/kepicenanoʔ/	'cut'
	/notoxonoʔ/	/kenotoxonoʔ/	'hoe'
	/netalenoʔ/	/kenetalenoʔ/	'lick'
	/naxacenoʔ/	/kenaxacenoʔ/	'make a fire'
	/yamaxanoʔ/	/keyamaxanoʔ/	'paint a face'
	/naweleno ʔ/	/kenaweleno ʔ/	'spread'

Compare this with the surface form of the verbs:

(45)

unprefixed	*prefixed*	
picnanoʔ	kepcenanoʔ	'cut'
notxonoʔ	kentoxonoʔ	'hoe'
netlenoʔ	kentalenoʔ	'lick'
naxcenoʔ	kenxacenoʔ	'make a fire'
yamxanoʔ	keymaxanoʔ	'paint a face'
nawlenoʔ	kenweleno?	'spread'

The relation between the underlying forme in (44) and surface forms in (45) is simple. Each is subject to a rule deleting the second vowel of the word.

(46) V → ∅ / # CVC __

Whether the first or second stem vowel is deleted depends on whether a prefix is present.

Apart from illustrating the point that underlying forms of words may not correspond to any single column in a word's paradigm, this discussion of Tonkawa illustrates two important characteristics of a phonological analysis. The first is that one analyzes data by advancing an initial hypothesis, and then refining the hypothesis as it becomes necessary. Thus we began with the hypothesis that the underlying forms were /picna/, /notxo/, /netle/ and so on, and were able to acount for a certain amount of data based on that hypothesis, but later modified our hypothesis about underlying forms to be /picena/, /notoxo/, /netale/ and so on. In other words, although our first hypothesis turned out to be wrong, it was close to right, and we were able to identify the source of the problem in our hypothesis and correct it.

The second characteristic of our analyis is that we always seek ways to test the predictions of our hypotheses. The hypothesis that the stems are underlying /picna/, /notxo/, /netle/ etc. makes a prediction, that if a vowel were ever to appear between the second and third consonants (for example due to a rule of vowel insertion), it would always be a single consistent and predictable vowel (since we are saying that it is not in the underlying form). The fact that a *different* vowel appears in *wepc**e**noʔ, went**o**xoʔ, went**a**loʔ* and *wenx**a**coʔ* shows that the prediction of this hypothesis is wrong, and this forced us to consider the alternative hypothesis that the underlying form contains a vowel between the second and third consonants: this hypothesis proved to be correct. The most basic form of hypothesis testing that is done in phonology is combining presumed forms of roots and affixes, and mechanically applying the rules which you assume in the analysis. If the wrong form is produced by this test, something is wrong with the hypothesis — either the underlying forms are wrong, or the rules are stated incorrectly (or the rules are being applied in the wrong order, a point we get to in the next chapter).

Summary

Establishing the correct underlying representation for a morpheme is the most important first step in giving a phonological analysis of data. A correct underlying representation unifies surface variants of a morpheme, giving recognition of the basic "sameness" of a morpheme, regardless of variations in pronunciation which arise because phonological rules have applied. The underlying form and the system of rules are thus connected: by making the right choice of underlying form, and given the right system of rules, the rules will correctly operate on just those segments which participate in the alternation. The key to making the right decision about underlying forms is to carefully consider different hypotheses: if a segment in a morpheme has two or more surface realisations, it is often necessary to consider two or more possibilities for what is underlying — is variant [a], [b] or [c] the right choice? The main issue relevant to answering this question is knowing which variant preserves important distinctions and which neutralises distinctions. The underlying form may not even be seen directly in any one pronunciation of a morpheme: it may be a form inferred from considering a number of specific instantiations of the morpheme.

Exercises

1. Axininca Campa

Provide underlying representations and a phonological rule which will account for the following alternations.

toniro	'palm'	notoniroti	'my palm'
yaarato	'black bee'	noyaaratoti	'my black bee'
kanari	'wild turkey'	noyanariti	'my wild turkey'
kosiri	'white monkey'	noyosiriti	'my white monkey'
pisiro	'small toucan'	nowisiroti	'my small toucan'
porita	'small hen'	noworitati	'my small hen'

2. Kikuyu

What is the underlying form of the infinitive prefix in Kikuyu? Give a rule that explains the non-underlying pronunciation of the prefix.

γotɛŋɛra	'to run'	γokuua	'to carry'
γokoora	'to root out'	koruγa	'to cook'
kooria	'to ask'	komɛɲa	'to know'
kohɔta	'to be able'	γočina	'to burn'
koγeera	'to fetch'	kohetoka	'to pass'
koniina	'to finish'	koina	'to dance'
γočuuka	'to slander'	γokaya	'to cut'
koγaya	'to divide'		

3: Korean

Give the underlying representations of each of the verb stems found below; state what phonological rule applies to these data. [Note: there is a vowel harmony rule which explains the variation between final *a* and *ə* in the infinitive, which you do not need to be concerned with]

Infinitive	*Conjunctive*	
ipə	ipk'o	'wear'
kupə	kupk'o	'bend'
kap^{h}a	kapk'o	'pay back'
cip^{h}ə	cipk'o	'feel the pulse'
tatə	tatk'o	'close'
put^{h}ə	putk'o	'adhere'
məkə	məkk'o	'eat'
čukə	čukk'o	'die'
ikə	ikk'o	'ripen'
tak'a	takk'o	'polish'
k'ak'a	k'akk'o	'reduce expenses'
sək'ə	səkk'o	'mix'

4: Hungarian

Explain what phonological process affects consonants in the following data (there is a vowel harmony rule which makes vowel in suffixes be back after back vowels and front after front vowels, which you do not need to account for). State what the underlying forms are for all morphemes.

noun	*in N*	*from N*	*to N*	*gloss*
kalap	kalabban	kalapto:l	kalapnak	hat
ku:t	ku:dban	ku:tto:l	ku:tnak	well
ža:k	ža:gban	ža:kto:l	ža:knak	sack
re:s	re:zben	re:stö:l	re:snek	part
šro:f	šro:vban	šro:fto:l	šro:fnak	screw
laka:š	laka:žban	laka:što:l	laka:šnak	apartment
ketret^{s}	ketred^{z}ben	ketret^{s}tö:l	ketret^{s}nek	cage
test	tezdben	testtö:l	testnek	body
rab	rabban	rapto:l	rabnak	prisoner
ka:d	ka:dban	ka:tto:l	ka:dnak	tub
meleg	melegben	melektö:l	melegnek	warm
vi:z	vi:zben	vi:stö:l	vi:znek	water
vara:ž	vara:žban	vara:što:l	vara:žnak	magic
a:g^{y}	a:g^{y}ban	a:k^{y}to:l	a:g^{y}nak	bed
sem	semben	semtö:l	semnek	eye
bün	bünben	büntö:l	bünnek	crime

toroñ	toroñban	toroñto:l	toroñnak	tower
fal	falban	falto:l	falnak	wall
ö:r	ö:rben	ö:rtö:l	ö:rnek	guard
sa:y	sa:yban	sa:yto:l	sa:ynak	mouth

5: Kikuria

Provide appropriate underlying representations and phonological rules which will account for the following data.

verb	*verb for*	
suraaŋga	suraaŋgera	'praise'
taaŋgata	taaŋgatera	'lead'
baamba	baambera	'fit a drum head'
reenda	reendera	'guard'
rema	remera	'cultivate'
hoora	hoorera	'thresh'
roma	romera	'bite'
heetoka	heetokera	'remember'
sooka	sookera	'respect'
tegeta	tegetera	'be late'
tačora	tačorera	'tear'
siika	seekera	'close'
tiga	tegera	'leave behind'
ruga	rogera	'cook'
suka	sokera	'plait'
huuta	hootera	'blow'
riiŋga	reeŋgera	'fold'
siinda	seendera	'win'

6: Farsi

Give the underlying forms for the following nouns, and say what phonlogical rule is necessary to explain the following data.

singular	*plural*	*gloss*
zæn	zænan	woman
læb	læban	lip
hæsud	hæsudan	envious
bæradær	bæradæran	brother
bozorg	bozorgan	big
mæleke	mælekean	queen
valede	valedean	mother
kæbire	kæbirean	big
ahu	ahuan	gazelle

hamele	hamelean	pregnant
bačče	baččegan	child
setare	setaregan	star
bænde	bændegan	slave
azade	azadegan	freeborn
divane	divanegan	insane

7: Tibetan

Numbers between 11 and 19 are formed by placing the appropriate digit after the number 10, and multiples of 10 are formed by placing the appropriate multiplier before the number 10. What are the underlying forms of the basic numerals, and what phonological rule is involved in accounting for these data?

ǰu	'10'	ǰig	'1'	ǰugǰig	'11'
ši	'4'	ǰubši	'14'	šibǰu	'40'
gu	'9'	ǰurgu	'19'	gubǰu	'90'
ŋa	'5'	ǰuŋa	'15'	ŋabǰu	'50'

8: Makonde

Explain what phonological rules apply in the following examples (the acute accent in these example marks stress, whose position is predictable).

repeated imperative	*past*	*imperative*	*gloss*
amáŋga	amíle	áma	move
taváŋga	tavíle	táva	wrap
anáŋga	aníle	ána	forge
akáŋga	akíle	áka	hunt
patáŋga	patíle	póta	twist
tatáŋga	tatíle	tóta	sew
dabáŋga	dabíle	dóba	get tired
aváŋga	avíle	óva	miss
amáŋga	amíle	óma	pierce
tapáŋga	tapíle	tépa	bend
patáŋga	patíle	péta	separate
aváŋga	avíle	éva	separate
babáŋga	babíle	béba	hold like a baby
aŋgáŋga	aŋgíle	éŋga	cut
putáŋga	putíle	púta	wash
utáŋga	utíle	úta	smoke
lukáŋga	lukíle	lúka	plait
lumáŋga	lumíle	lúma	bite
uŋgáŋga	uŋgíle	úŋga	tie

iváŋga	ivíle	íva	steal
pitáŋga	pitíle	píta	pass
imbáŋga	imbíle	ímba	dig
limáŋga	limíle	líma	cultivate

9: North Saami

Posit appropriate underlying forms and any rules needed to explain the following alternations. The emphasis here should be on correctly identifying the underlying form: the exact nature of the changes seen here is a more advanced problem.

Nominative sg.	*Essive*	
varit	varihin	"2 year old reindeer buck"
oahpis	oahpisin	"acquaintance"
čoarvuš	čoarvušin	"antlers & skullcap"
lottaaš	lottaaǰin	"small bird"
čuoivvat	čuoivvagin	"yellow-brown reindeer"
ahhkut	ahhkubin	"grandchild of woman"
suohkat	suohkaðin	"thick"
heeǰoš	heeǰoǰin	"poor guy"
aaǰǰut	aaǰǰubin	"grandchild of man"
beškoš	beškoǰin	"roof swallow"
bissobeaht^{s}et	bissobeaht^{s}ehin	"butt of gun"
čeaht^{s}it	čeaht^{s}ibin	"children of elder brother of man"
yaaʔmin	yaaʔmimin	"death"
čuoivat	čuoivagin	"yellow-grey reindeer"
laageš	laageǰin	"mountain birch"
gahpir	gahpirin	"cap"
gaauht^{s}is	gaauht^{s}isin	"8 people"
aaslat	aaslagin	man's name
baðoošgaatt^{s}et	baðoošgaatt^{s}ebin	"bird type"
ahhkit	ahhkiðin	"boring"
bahaanaalat	bahaanaalagin	"badly behaved"
beštor	beštorin	"bird type"
heevemeahhtun	heevemeahhtunin	"inappropriate"
beeǰot	beeǰohin	"white reindeer"
bissomeahtun	bissomeahtumin	"unstable"
laðas	laðasin	"something jointed"
heaiyusmielat	heaiyusmielagin	"unhappy"
heaŋkkan	heaŋkkanin	"hanger"
yaman	yamanin	"something that makes noise"

[Note: it is suggested that the student return to this example after reading Chapter 6, and consider the formalization of this process using distinctive features]

Advanced Topics and Readings

The content of underlying representations. A basic issue regarding underlying forms is: what are they made of? We have so far treated them as segments represented as letters. In Chapter 6 (and again in Chapter 11), representations are revisited, and it is shown that segments are not atomic units but are defined in terms of a small set of phonetically defined universal features. Correspondingly, underlying forms are composed of sets of features, and not unanalyzable segments per se.

Chapter 10 addresses the famous abstractness issue, concerning the extent to which underlying forms can differ from surface forms. We have partially addressed that issue here, showing that the underlying form is not necessarily a substring of any one word that contains the morpheme. Hence in Palauan, the two vowels of /daŋob/ are never both present as full vowels in any single instantiation of the root; in Tonkawa, the root /picena/ is never directly seen in that form, since one of the vowels always deletes. The main question addressed in Chapter 10 is whether an underlying form may even contain segments which are never pronounced as such in the language.

Morphology and morphophonemics. In the taxonomic phonemic tradition, phonological rules of the type discussed in this chapter were referred to as morphophonemic rules (a name still used occasionally to describe phonological processes). The implication is that there is a connection between morphology and such phonological processes. Allophonic rules do not neutralize distinctions between underlying segments, so the underlying form can be automatically inferred from the surface form — per the condition of biuniqueness, an allophone is always a member of exactly one phoneme, thus reconstruction of the phoneme which a surface sound comes from is automatic if you know the rule. With the output of a neutralizing rule (such as those presented in this chapter) it is impossible to know which of two (or more) segments a surface segment X derives from if you only look at the word itself, even if you know the system of rules. One must look at a different instantiation of the segment, appearing in some other context, in order to determine what the underlying segment is. Most often, the other context which provides the crucial evidence must be a word with a morphological relation to the word in question, such as an infinitive of a verb, compared to a 1sg present tense form (as was needed to distinguish /h/ and /p/ in Kikerewe, which neutralize to [p] after a nasal). For that reason, neutralizing phonological alternations are most often associated with different morphological forms of words: hence the term "morphophonemics", which is the selection of a particular (taxonomic) phoneme in some context.

In the taxonomic approach, morphophonemic rules are often seen as selecting **allomorphs** of a morpheme. Analogous to the phoneme being seen as the set of all phones that realise the phoneme, the morpheme is seen as being made up of morphophonemes — the phoneme-strings that realise the morpheme, as well as

auxiliary symbols used to represent processes. As an example of the latter kind of symbol, the morphophoneme ||≃|| is used in Miller's 1965 grammar of Acoma to indicate that the preceding vowel is deleted; ||M|| indicates a labial nasal which is retained before a particular list of suffixes and is deleted elsewhere; ||B|| symbolizes a consonant that is realised as [b] before certain vowel-initial suffixes, and deletes otherwise. In the case of Tonkawa, the morpheme which might be symbolized as ||notoxo|| "hoe", using one of the notations for denoting a morphemic representation, is realised by the set of allomorphs {/ntox/, /ntoxo/, /notx/, /notxo/}, and the morpheme ||picena|| represents the set {/pcen/, /pcena/, /picn/, /picna/}. Morphophonemics would refer to some set of rules that select particular variants in some context, just as there are rules that select the variants of the English verb morpheme ||be||, namely {/ɪz/, /wəz/, /wr/, /æm/, /ar/}.

Not all neutralizing phonological rules involve changes in morphology: the defining context for a rule might be surrounding words in a sentence. We saw this in Korean, with a rule nasalizing stops before a nasal consonant. This rule applies even at the sentence level, so the pronunciation of the word /pap/ "rice" varies between [pap] and [pam], depending on which word follows: the morphological form of the word /pap/ — uninflected noun — remains constant in [pam məkəra] "eat rice" and [pap twemnita] "served rice", even though the pronunciation of the word changes. There is a rich literature addressing such neutralizing phonological rules at the sentence level: see for example Kisseberth & Abasheikh 1974, Clements 1978, Odden 1987. Most examples of sentence-level phonology involve just the consideration of a word an an immediately preceding or following word; however, Odden & Robert-Kohno 1999 and Odden 2000 discuss phrasal processes in Kikamba and Zinza which apply across unbounded sequences of words. See Inkelas & Zec 1995 and references therein for various theoretical perspectives on phrasal phonological rules.

The relation of phonology to morphology. A different view of the relationship between phonology and morphology is presented in the theory of Lexical Phonology (Kiparsky 1982, Kaisse & Shaw 1985, Mohanan 1986). In that model, phonology and morphology are separate but bidirectionally interacting components in a grammar. Rules are assigned to particular strata or levels in both phonology and morphology. Certain morphological operations are defined for the first stratum of the morphological component — Level 1 — so in English, affixation of the derivational affixes -*ion* and -*ity* takes place at Level 1, and other operations such as affixation of -*ness* and -*ing* are defined at Level 2. Similarly, certain phonological rules are defined for Level 1 but not Level 2, for example stress assignment and Trisyllabic Shortening (which accounts for the vowel alternation in *profane* ~ *profanity*) which apply only when Level 1 affixes are added.

Under this model, the output of Level 1 morphology undergoes the rules of Level 1 phonology. The result derived from Level 1 phonology is then resubmitted to the morphological component, and at Level 2 other affixes are added, with the

resulting form again being run through the phonology. Thus the derivation of a word, in the view of Lexical Phonology, involves a shuttling back and forth between the morphological component and the phonolological component. Accordingly, each input to the phonology (at Level 1 vs. Level 2) would be the underlying form, at that level.

Morpheme structure conditions and rules. One of the more resilient problems regarding underlying forms is that they seem to exhibit regular properties. For instance, there are no morphemes in English which begin with sequences such as **bn*, **km*, **gn*; in Korean, no noun stems end with the consonants *p'*, *t'*, *k'*, or, for that matter, *t*; Russian has no underlying consonants plain /č/, palatalized /ž^{y}/, or /γ/. If all regularities about languages are to be stated in a grammar, how are these facts to be expressed?

One answer, exemplified by Halle 1959, is that there are **morpheme structure rules** (MSR) in a grammar which perform specific repairs on any string not conforming to such rules. Thus there could be a rule of Russian that would converts any non-palatalized (phonetically non-existent) /č/ into palatalised [č^{y}]. Paired with the assumption that there are such rules is that certain properties are left blank underlyingly, so in Russian the palatalization feature would not be underlyingly specified for the alveopalatal affricate, and would be filled in by a rule. An alternative to this is **morpheme structure conditions** (MSC) as proposed by Stanley 1967 which do not 'actively' change underlying forms, but rather 'passively' impose requirements on what is a well-formed morphemes. In the MSC approach, underlying representations will contain fully specified segments, thus the voiceless alveopalatal affricate of Russian is definitively palatalized, and not left in a "blank" state for palatalization.

The major criticism of the MSC approach is to so-called "duplication problem" identified in Kenstowicz & Kisseberth 1977, that the MSC's required under the latter approach are often the same as active segment-changing rules motivated by the existence of paradigmatic alternations. For example in Kiruundi, all vowels within roots are underlyingly long when followed by a sequence of a nasal plus a consonant — an example is [riinda] "watch", which can be explained by a MSC requiring vowels to be long before NC. There is also an active alternation in vowel length triggered by combination of underlying short vowels plus NC sequences, which explains the variation in the length of the infinitive prefix /ku-/ seen between [ku-rora] "to look at" vs. [kuu-n-dora] "to look at me". The MSC on underlying length duplicates the phonological rule which must exist anyway.

It does not solve the problem to derive morpheme-internal vowel length in [riinda] by simply applying this rule to an underlying short vowel, assuming that all vowels are underlyingly short before tautomorphemic NC. Under the principle that all regularities must be stated in the grammar, this just replaces the duplication problem with a "mirror-image duplication" problem, that if there is a rule deriving X in a context, there must be a MSC ruling out X in that context.

One contemporary trend in phonology, Optimality Theory, theoretically precludes the possibility of a grammar with statements about underlying forms. This has resulted in the principle "Richness of the Base" (Prince & Smolensky 1993), variously understood as saying "any imagineable input must map to some output" or "any string must map to a well-formed output", ideas which have in common the denial that a grammar states regularities about underlying forms. One significant shift of emphasis in that approach, discussed under the rubric "Stampean occultation" and "lexicon optimization" (see also Inkelas 1994), is that some observable regularities may not be part of a formal grammar. The lack of any underlying /ü/ in the lexicon of English words might thus not be accounted for in the formal theory of grammar, but emerges as a byproduct of language acquisition — in a nutshell, there is no reason to assign /ü/ to the underlying form of any words of English. This seems to be a major break with previous tradition, since it rejects the idea that all generalizations about a language need to be explicitly encoded in a grammar. This question remains unresolved at present.

5

Interacting Processes

In this chapter, you will broaden your understanding of how phonological systems work by

- looking at more complex patterns of phonological alternation
- seeing how complex surface patterns of alternations result from the interaction of different but related phonological rules
- understanding the effect of different rule orderings on how an underlying form is changed into a surface form

Phonological systems are not made up of isolated and unrelated phonological rules: there are usually significant interactions between phonological processes. This chapter concentrates on two related topics. First, the fact that a seemingly complex set of alternations can often be given a simpler explanation if one separates the effect of different rules which often happen to apply in the same form. Second, applying rules in different orders can have a significant effect on the way that a given underlying form is mapped onto a surface form.

1. Separating the Effects of Different Rules

Very often, when you analyze phonological alternations, insights into the nature of these alternations are revealed once you realise that a word may be subject to more than one rule, both of which which can affect the same segment. If you think just in terms of a direct statement of the relation between underlying segments and their surface realisation, and that the environment is where each particular mapping takes place, the resulting description is likely to be confusing and complex, and will miss a number of important generalizations. But if you look for ways to decompose the problem into separate parts, which either have different effects on a segment that accumulate to give a seemingly complex pattern of phonetic change, or which have different natural contexts that sum up to what looks

like an unnatural collection of conditioning environments, one can generally provide a simpler description of the language.

1.1. Votic Palatalization and Raising/Fronting

The following example from Votic illustrates one way in which the account of phonological alternations can be made tractable by analysing the alternations in terms of interaction between independent phonological processes. In these examples, [ɫ] represents a velarized *l*.

(1)

	nominative	partitive	gloss
a.	vərkko	vərkkoa	net
	čako	čakoa	cuckoo
	lintu	lintua	bird
	saatu	saatua	garden
	yałka	yałkaa	foot
	bočka	bočkaa	barrel
	einæ	einææ	hay
	vævü	vævüæ	son-in-law
b.	siili	siiliæ	hedgehog
	łusti	łustia	pretty
c.	yarvi	yarvəa	lake
	mæči	mæčeæ	hill
	čivi	čiveæ	stone
d.	kurči	kurkəa	stork
	əłči	əłkəa	straw
	kahči	kahkəa	birch

The first group of examples (1a) show that the nominative has no suffix, and the partitive has the suffix *-a* or *-æ* (the choice depends on the preceding vowels, determined by a vowel harmony rule according to which a suffix vowel is front if the preceding vowel is front. The rule ignores [i], but if no vowel other than [i] precedes, the harmony rule makes the suffix vowel be front). The second group of examples (1b) illustrates this same point, specifically in roots which have /i/ as the underlying final vowel of the root. The nouns in the third group (1c) illustrate a phenomenon of final vowel raising and fronting (which we have previously seen in closely related Finnish), whereby *e* and *ə* become [i] word-finally.

(2) *Final fronting/raising*
mid non-round vowel → front high / __ #

The essential difference between the examples of (1b) and (1c) is that the forms in (1b) underlyingly end in the vowel /i/, and those in (1c) end in /e/ or /ə/. In the last set of examples (1d), the noun root underlyingly ends in the sequence /kə/, which can be seen directly in *kurkə-a*. However, the final CV of the root appears as [či] in the nominative *kurči*.

It would be unrevealing to posit a rule changing word final /kə/ into [či] in one step. The problem with such a rule is that the change of a velar to a palatal conditioned by following word-final schwa is not a process found in other languages, and depends on a very specific conjunction of facts, that is, not just schwa, but word-final schwa. Such a rule treats it as a coincidence that the underlying final schwa actually becomes [i] on the surface. This alternation makes more sense once it is decomposed into the two constituent rules which govern it, namely final raising (independently motivated by the data in (c)). Applying this rule alone to final /kə/ would result in the sequence [ki]. However, [ki] is not an allowed CV sequence in this language, and a process of palatalization takes place, in accordance with the following rule.

(3) *Palatalization*
k → č / ___ i

We can thus account for the change of underlying /kurkə/ and /əłkə/ to [kurči] and [əłči] by applying these two rules in a specific order, where the rule of vowel raising applies before palatalization, so that vowel raising is allowed to create new occurrences of the vowel [i], and those derived cases of [i] condition the application of palatalization.

(4)	/kurkə/	*underlying*
	kurki	*vowel raising*
	kurči	*palatalization*

1.2. Tagalog Syncope and o-raising

A similar example of the interaction between phonological processes is seen in (5), which gives the uninflected form of certain roots in Tagalog, along with derived forms involving the suffix -*in* and -*an*.

(5)	bukas	buksin	buksan	'open'
	kapit	kaptin	kaptan	'embrace'
	damit	damtin	damtan	'clothe'
	laman	lamnin	lamnan	'fill'

putol	putlin	putlan	'cut'
tobos	tubsin	tubsan	'redeem'
opos	upsin	upsan	'stop'
posod	pusdin	pusdan	'tuft'

It is evident that there is a rule which deletes the second vowel of the root when it is preceded by a VC (an open syllable) and followed by a CV sequence (is iteself in an open syllable). This is an example of a process which is rather common crosslinguistically and is referred to as *syncope*, formulated below in the fashion that is appropriate for Tagalog.

(6) *Syncope*
$V \rightarrow \varnothing$ / VC __ CV

Application of just this rule explains the variations in the form of the root in *bukas* ~ *buksin*, *putol* ~ *putlin* and so on. The final three examples illustrate a further complexity, which is that when the second vowel is deleted, the first vowel changes from /o/ to [u]. Rather than attempting to construct a single rule which both deletes the vowel of the second syllable and raises certain vowels in the first syllable, or trying to incorporate a condition on a vowel raising rule such as "when the second root vowel deletes", it is simpler to let the syncope rule apply automatically, and deal with any additional changes by independent rules. If the syncope rule is applied to underlying /tobosan/, the result would be *tobsan*, and if the grammar of Tagalog contained a syncope rule, this is how we predict the word would be pronounced. In order to discover how to state the new rule which gets from the intermediate form *tobsan* to [tubsan], we focus on what change in the environment has been brought about by applying syncope. The actual phonetic form [tubsan] differs in the height of the vowel in the first syllable — the question is, why does the first vowel raise just in case the second vowel deletes. The indirect effect of the vowel deletion rule is that it creates a cluster of two consonants. This observation, coupled with the further observation that the vowel [o] does not appear before a cluster of consonants in our data, leads us to surmise that there is a phonological rule which raises the vowel /o/ to [u] when it is followed by two consonants.

(7) *Pre-cluster o-raising*
$o \rightarrow u$ / __ CC

Again, the derivation of the phonetic forms [tubsan], [upsan], [pusdan] and so on involves the interaction of two rules. The rule of syncope deletes the second root vowel, which creates the cluster of consonants that is crucial to the application of vowel raising.

(8)	/tobosan/	*underlying*
	tobsan	*syncope*
	tubsan	*o-raising*

Our account of these alternations is rendered much simpler if these alternations are accounted for by two independent processes which apply in a particular order. Notice that the order in which these processes apply is important, for if we were to attempt to apply the rule of o-raising first, to underlying /tobosan/, the conditions required by the rule are not satisfied: in order for the change to take place, there must be a cluster of consonants, which has not yet been created. If we then proceed to apply syncope, the incorrect form *[tobsan] would result, since the rule of vowel raising would have already been bypassed.

1.3. Kikamba Palatalization and Glide Formation

There is a phonological process in Kikamba whereby the combination of a velar consonant plus the glide *y* fuse into an alveopalatal affricate. This can be seen in (9), which involves the plain and causative forms of verbs. In the examples on the left, the verb is composed of the infinitive prefix /ko-/ (which undergoes a process of glide formation before another vowel, becoming [w]) followed by the verb root (e.g. -*kam*- 'milk'), plus an inflectional suffix -*a*. In the righthand column one can see the causative of the same verb, which is formed by suffixing -*y*- after the verb root before the inflectional marker -*a*.

(9)		*plain*	*causative*	*gloss*
	a.	kokámá	kokámyá	milk
		kokonà	kokonyà	hit
		kokɛðà	kokɛðyà	harvest
		kokɔ́má	kokɔ́myá	sleep
		kolááàmbà	kolááàmbyà	lap
		komiìnà	komiìnyà	finish
		kotálá	kotályá	count
		kwaambatà	kwaambatyà	go up
		kwaànà	kwaànyà	tell
		kwaàðà	kwaàðyà	govern
		kwéétá	kwéétyá	answer
		kwíímbá	kwíímbyá	swell
	b.	koβikà	koβičà	arrive
		koβálokà	koβáločà	fall
		kolikà	količà	enter
		kolɛ́ɛ̀ŋgà	kolɛ́ɛ̀ñjà	aim
		kosɔ́ɔ̀ŋgà	kosɔ́ɔ̀ñjà	dance
		kokɔlɔkà	kokɔlɔčà	stir

kwɛ̋ɛ̋ŋgá̋	kwɛ̋ɛ̋ñjá̋	clear a field
kwaanekà	kwaanečà	dry
kwɔ̋ɔ̋ká̋	kwɔ̋ɔ̋čá̋	gather coals
kwá̋á̋ká̋	kwá̋á̋čá̋	build
kweenokà	kweenočà	go home

The examples in (a) illustrate the causative affix following various non-velar consonants of the language. In (b), one can see the causative of various roots which end in *k* or *g*, where by analogy to the data in (a) one predicts the causatives /koβikyà/, /koβálokyà/, /kolɛ̋ɛ̀ngyà/ and so on. Instead of the expected consonant sequences *ky*, *gy*, one finds instead that the velar consonant has been replaced by an alveopalatal affricate, due to the following rule.

(10) *Palatalization*
ky, gy → č, ǰ

Examples of glide formation are seen in (9), where the vowel /o/ becomes [w] before another vowel. This process of glide formation is further illustrated in (11) and (12). In (11), we can see across all of the columns that the prefix for the infinitive is /ko/, and appears phonetically as such when it stands before another consonant. The last three data columns show that the prefixes marking different classes of objects are /mó/ for class 3, /mé/ for class 4, and /ké/ for class 7 (Kikamba nouns have a dozen grammatical agreement classes, analogous to gender in better-known European languages).

(11)

to V	*to V it* (*cl.3*)	*to V them* (*cl.4*)	*to V it* (*cl.7*)	
koðukà	komóðukà	koméðukà	kokéðukà	churn
kokaàðà	komókaàðà	komékaàðà	kokékaàðà	praise
koliìndà	komóliìndà	koméliìndà	kokéliìndà	cover
komɛ̋ɛ̋ná̋	komómɛ̋ɛ̋ná̋	komémɛ̋ɛ̋ná̋	kokémɛ̋ɛ̋ná̋	hate
koñuβà	komóñuβà	koméñuβà	kokéñuβà	choose

When the verb root begins with a vowel, one would predict a sequence of vowels such as **koasya* for 'to lose'. Vowel sequences are avoided in Kikamba by the application of the rule of glide formation, according to which any non-low vowel becomes a glide before another vowel.[1]

[1] The stem-initial vowel in these examples becomes long, as a side-effect of the preceding vowel becoming a glide: this is known as **compensatory lengthening**.

(12)

to V	*to V it* (*cl.3*)	*to V them* (*cl.4*)	*to V it* (*cl.7*)	
kwa̋ásya̋	komwa̋ásya̋	komya̋ásya̋	kočáásya̋	lose
kwa̋áka̋	komwa̋áka̋	komya̋áka̋	kočááka̋	build
kwaàsà	komwa̋àsà	komya̋àsà	kočáàsà	carve
kóómba̋	komóómba̋	komyóómba̋	kočóómba̋	mold
kookelyà	komóokelyà	komyóokelyà	kočóokelyà	lift
kúúna̋	komúúna̋	komyúúna̋	kočúúna̋	fetch
kuumbekà	komúumbekà	komyúumbekà	kočúumbekà	bury
kwɛ̋ɛ̋nza̋	komwɛ̋ɛ̋nza̋	komyɛ̋ɛ̋nza̋	kočɛ̋ɛ̋nza̋	shave
kwɛɛ̀ndà	komwɛ̋ɛ̀ndà	komyɛ̋ɛ̀ndà	kočɛ̋ɛ̀ndà	like
kwɔ̋ɔ̋na̋	komwɔ̋ɔ̋na̋	komyɔ̋ɔ̋na̋	kočɔ̋ɔ̋na̋	see
kwɔ̋ɔ̋sa̋	komwɔ̋ɔ̋sa̋	komyɔ̋ɔ̋sa̋	kočɔ̋ɔ̋sa̋	take
kwɔ̋ɔ̋βa̋	komwɔ̋ɔ̋βa̋	komyɔ̋ɔ̋βa̋	kočɔ̋ɔ̋βa̋	tie

The glide formation rule can be formalized as (13).

(13) *Glide formation*
ɛ,o → y,w / ___ V

This rule would be expected to apply to underlying forms such as /ko-una/ 'to fetch' and /ko-omba/ 'to mould', since those forms have an underlying sequence of a vowel /o/ followed by another vowel. Applying that rule would result in *[kwúúna̋] and *[kwóómba̋], but these are not the correct forms. We can resolve this problem once we observe that the glide [w] never appears between a consonant and the two highest round vowels [u,o] (it can appear before the vowel [ɔ], as seen in [kwɔ̋ɔ̋na̋] 'to see' from /ko-ɔna/).

It does not help to restrict rule (13) so that it does not apply before /o,u/, since the vowel /e/ does actually undergo glide formation before these vowels (/ko-me-okelya/ becomes [komyóokelyà] 'to lift them' and /ko-mé-úna̋/ becomes [komyúúna̋] 'to fetch them'). The seeeming restriction on glide formation is highly specific: the round vowel fails to surface as a glide only if the following vowel is *o* or *u*. Furthermore, the round vowel does not merely fail to become a glide, it actually deletes, so we can't just block (13) before [u,o] since that would give *[koúna̋] and *[kóómba̋]). Two rules are required to account for these vowel plus vowel combinations. A very simple solution to this problem is to allow the most general form of the glide formation rule to apply, imposing no restrictions, and derive the intermediate forms *kwúúna̋* and *kwóómba̋*. Since we have observed that the surface sequences [Cwo] and [Cwu] (where "C" is "any consonant") is lacking in the language, we may posit the following rule of glide-deletion, which explains both why such sequences are lacking and what happened to the expected glide in the intermediate forms.

(14) *Homorganic glide deletion*
w → ∅ / C ___ o,u

The interaction between these processes, that the general glide formation rule first creates a glide, which is then deleted in a restricted subset of forms by (14), is expressed by ordering glide formation before glide deletion.

Another crucial rule interaction is between glide formation and palatalization. Palatalization specifically applies to the sequences *ky* and *gy*, which involve glides, and glide formation creates glides from vowels, whose creating can trigger application of palatalization. This is shown in the derivation of [kočáásyá] from /ko-ké-áásyá/.

(15)	/ko-ké-áásyá/	*underlying*
	kokyáásyá	*glide formation*
	kočáásyá	*palatalization*

Thus glide formation creates phonological structures which are crucially referenced by other phonological rules.

1.4. Bukusu nasal+consonant combinations

The theme which we have been developing in this chapter is that phonological grammars are composed of simpler elements that interact in sometimes complex ways, and that this factoring-out of the fundamental processes is an essential part of phonological analysis. In the examples which we have considered above, such as vowel raising/fronting and velar palatalization in Votic, or syncope and vowel raising in Tagalog, or glide formation and palatalization in Kikamba, the phonological processes have been sufficiently different that it would be very difficult to subsume these processes under one rule. Often, a language may have a set of phonological changes which are very similar in nature, or which apply in very similar or even identical environments, and the question arises whether the alternations in question reflect a single phonological rule. Or, do the alternations reflect the operation of more than one independent rule, with only accidental partial similarity? Such a situation arises in Bukusu, where a number of phonological changes affect the combination of a nasal plus a consonant. Here, we are faced with a set of similar phonological changes — changes in consonants which are preceded by nasals — and the question is whether these processes should be combined into one rule?

Place assimilation and voicing. In the first set of examples in (16), a voicing rule applies which makes all underlyingly voiceless consonants voiced when preceded by a nasal, in this case the prefix for the 1s present tense subject which is /n/. The underlying consonant at the beginning of the root is revealed directly when the

root is preceded by the 3p. prefix *βa-*, or when there is no prefix as in the imperative.

(16)

imperative	*3p. pres.*	*1s. pres*	*gloss*
ča	βača	ñ̃ja	go
čexa	βačexa	ñ̃jexa	laugh
čosa	βačosa	ñ̃josa	prick
čučuuŋga	βačučuuŋga	ñ̃jučuuŋga	sieve
čuxa	βačuxa	ñ̃juxa	pour out
taa	βataa	ndaa	draw water
talaanda	βatalaanda	ndalaanda	go around
teexa	βateexa	ndeexa	cook
tiira	βatiira	ndiira	get ahold of
paaŋga	βapaaŋga	mbaaŋga	arrange
piima	βapiima	mbiima	weigh
pakala	βapakala	mbakala	writhe in pain
keenda	βakeenda	ŋgeenda	walk
ketulula	βaketulula	ŋgetulula	pour out
kisa	βakisa	ŋgisa	hide
kona	βakona	ŋgona	pass the night
kula	βakula	ŋgula	buy
kwa	βakwa	ŋgwa	fall

We can state this voicing rule as follows.

(17) *Post-nasal voicing*
voiceless → voiced / nasal ___

You will also note that a nasal consonant always agrees in place of articulation with the following consonant, a process which we will notate informally as follows (where 'αplace....αplace' means 'the same place of articulation': this will be discussed in more detail in later chapters).

(18) *Nasal place assimilation*

$$\text{nasal} \rightarrow \alpha\text{place} \;/\; \_\_ \begin{bmatrix} \text{C} \\ \alpha\text{place} \end{bmatrix}$$

The data considered so far have not given clear evidence as to what the underlying place of articulation of the 1s. subject prefix is, since that nasal always assimilates to the following consonant. To determine that the prefix is indeed /n/, we turn to the form of stems which underlyingly begin with a vowel, where there is no assimilation. In the imperative, where no prefix precedes the stem, the glide

[y] is inserted before the initial vowel. (The data in (21) includes examples of underlying initial /y/, which is generally retained). When the 3p. prefix /βa/ precedes the stem, the resulting vowel sequence is simplified to a single non-high vowel. No rules apply to the 1s. prefix, which we can see surfaces as [n] before all vowels.

(19)	*imperative*	*3p. pres.*	*1s. pres*	*gloss*
	yiixala	βeexala	niixala	sit
	yaasama	βaasama	naasama	gape
	yoola	βoola	noola	arrive
	yeekesya	βeekesya	neekesya	show

One question that we ought to consider is the ordering of the rules of voicing and place assimilation. In this case, the ordering of the rules does not matter: whether you apply voicing first and assimilation second, or assimilation first and voicing second, the result is the same.

(20)		/n-kwa/		/n-kwa/
	voicing	ngwa	assimilation	ŋkwa
	assimilation	ŋgwa	voicing	ŋgwa

The reason why the ordering does not matter is that the voicing rule does not refer to the place of articulation of the nasal, and the assimilation rule does not refer to the voicing of the following consonant.

Post-nasal hardening. There is another process of consonant hardening which turns the voiced continuants into appropriate stops after a nasal: *l* and *r* become *d*, *β* becomes *b*, and *y* becomes *ǰ*.

(21)	*imperative*	*3p. pres.*	*1s. pres*	*gloss*
	lola	βalola	ndola	look
	lasa	βalasa	ndasa	shoot at
	leβa	βaleβa	ndeβa	push
	lela	βalela	ndela	nurse
	loβa	βaloβa	ndoβa	refuse
	lwaala	βalwaala	ndwaala	be sick
	lya	βalya	ndya	eat
	ra	βara	nda	put
	rara	βarara	ndara	be stung
	reeβa	βareeβa	ndeeβa	ask
	roβa	βaroβa	ndoβa	ripen
	roora	βaroora	ndoora	dream
	rusya	βarusya	ndusya	vomit
	rya	βarya	ndya	fear

βa	βaβa	mba	be
βaaka	βaβaaka	mbaaka	skin
βakala	βaβakala	mbakala	spread
βala	βaβala	mbala	count
βasa	βaβasa	mbasa	forge
βoola	βaβoola	mboola	tell
βukula	βaβukula	mbukula	take
yama	βayama	ñjama	scout
yaaya	βayaaya	ñjaaya	scramble with
yoola	βayoola	ñjoola	scoop
yaañja	βayaañja	ñjaañja	favor
yuula	βayuula	ñjuula	snatch

These data can be accounted for by the following rule.

(22) *Post-nasal hardening*
voiced continuant → stop / nasal ___

This statement of the rule illustrates a simplification often made in the way that rules are stated, that they are typically written to specify the bare essentials of the phonological change, leaving the exact phonetic consequences of the rule to be filled in by general conventions. Consider first the fact that /β/ becomes [b]: this change is accurately described just by the statement that voiced continuants become stops after nasals, since the only difference between [β] and [b] is that [β] is a continuant. However, [r] and [d] differ in two respects: first, [r] is a continuant, and second [r] is a sonorant whereas [d] is an obstruent. The question is, what would it mean for /r/ to change into a stop which was still a sonorant (as is implied by the rule statement (22))? Sonorant stops are not common in the languages of the world, and are generally restricted to nasals.[2] In analysing the change of /r/ to [d] as nothing more than a change from continuant to stop, we take advantage of the fact that some changes in phonetic value are automatic side effects of general principles of possible language sounds, and need not be stated in the rule itself. In the case of the change of /r/ to [d], the subsidiary change is from sonorant to obstruent status, being brought about by the fact the lack of oral sonorant stops in languages.

Analogous reasoning is seen in the change of /l/ to [d] after a nasal. The only other difference from the change of /r/ to [d] is that the resulting sound becomes non-lateral. What would be the result if /l/ were to simply change to being a stop? We expect a change to obstruent status, but what is a lateral obstruent? There

[2] The reason is the conflict between the aerodynamic requirements of sonorants and the effect of oral stops on airflow: sonorants require unimpeded airflow, but oral stops have no airflow.

actually is such a segment in some languages: a voiced lateral affricate [dˡ] does exist in Tlingit and Navaho. But such a segment is very rare, and in particular does not exist in Bukusu. Given the knowledge that the segment [dˡ] does not exist in Bukusu, one can preclude [dˡ] as being the actual output of a rule which makes /l/ be a stop.

This same approach explains why /y/ becomes [ʒ̃]. As with *r* and *l*, we expect a change of /y/ to being an obstruent. There does exist an obstruent stop corresponding to /y/ found in languages, namely [ɟ]. As with the imediately preceding case of /l/ becoming [d], we note that there is no segment [ɟ] in Bukusu. We will discover, as we investigate phonological patterns in various languages, that it is not unusual to encounter such effects, where certain classes of segments that are the output of phonological rule are subject to minor readjustments, to bring the result of the rule into conformity with general properties of segments in the language. When the results of a rule are subject to such adjustments, to bring the output into conformity with the phonemic inventory of the language, the rule is said to be **structure preserving**.

The independence of voicing and hardening. One might want to state these two processes, rules (17) and (22), as a single rule which both voices voiceless stops and makes voiced continuants into stops after a nasal, since in both cases, the consonant that appears after the nasal is a voiced stop. Rather than try to accomplish all of this with a single rule, we will assume that there are two separate rules, one which accounts for voicing and the other which turns continuants into stops. This way, each rule will perform a single phonetic change in one unified context: the question of just how much a single rule can actually do is discussed in more detail in later chapters.

Post-nasal l-deletion. A third process affecting sequences of nasal plus consonant can be seen in the following data.

(23)		*imperative*	*3p. pres.*	*1s. pres*	*gloss*
	a.	tima	βatima	ndima	run
		taaña	βataaña	ndaaña	hack
		tiiŋa	βatiiŋa	ndiiŋa	filter
		rema	βarema	ndema	chop
		riina	βariina	ndiina	run away
		ruma	βaruma	nduma	send
	b.	laanda	βalaanda	naanda	go around
		laaŋgwa	βalaaŋgwa	naaŋgwa	be named
		liinda	βaliinda	niinda	wait
		loma	βaloma	noma	say
		loondelela	βaloondelela	noondelela	follow
		luma	βaluma	numa	bite

The examples in (a) show the effect of rules of voicing and consonant-hardening, applying as expected to /t/ and /r/. However, the examples in (b) show the deletion of underlying /l/ after a nasal. These examples contrast with the first set of examples in (21), where the root also begins with underlying /l/: the difference between the two sets of verbs is that in the second set, where /l/ deletes, the following consonant is a nasal, whereas in the first set where /l/ does not delete, the next consonant is not a nasal.

The significance of the examples in (23a) is that although underlying /t/, /l/ and /r/ all become [d] after a nasal, the deletion of an underlying consonant in the environment N__VN only affects underlying /l/. Since the voicing and hardening rules would neutralize the distinction between the three consonants after a nasal but in fact /l/ acts differently from /t/ and /r/ in the context N__VN, we can deduce that there must be a rule deleting /l/ — but not /t/ or /r/ — in this context.

(24) *l-deletion*
$l \rightarrow \varnothing$ / nasal __ V nasal

Furthermore, this rule clearly must apply before the hardening rule changes /l/ into [d] after a nasal, since otherwise there would be no way to restrict this rule to applying only to underlying /l/. Once the hardening rule (22) applies, underlying /n-liinda/ would become *n-diinda*, but /n-riina/ would also become *n-diina*. Once that has happened, there would be no way to predict the actual pronunciations [niinda] and [ndiina].

On the other hand, if one were to apply the *l*-deletion rule first, the rule could apply in the case of /n-liinda/ to give [niinda], but would not apply to /n-riina/ because that form does not have an *l*: thus by crucially ordering the rules so that *l*-deletion comes first, the distinction between /l/, which deletes, and /r/, which does not delete, is preserved.

Nasal degemination. Another phonological process applies to consonants after nasal consonants. When the root begins with a nasal consonant, the expected sequence of nasal consonants simplifies to a single consonant.

(25)

imperative	*3p. pres.*	*1s. pres*	*gloss*
mala	βamala	mala	finish
manya	βamanya	manya	know
meela	βameela	meela	get drunk
ŋoola	βaŋoola	ŋoola	see into the spirit world
ña	βaña	ña	defecate
ñaaña	βañaaña	ñaaña	chew
ñwa	βañwa	ñwa	drink

Thus, in the case of 'I finish', the underlying form would be /n-mala/ which would undergo the place assimilation rule (18), resulting in *mmala*. According to the data we have available to us, there are no sequences of identical consonants in the language, so it is reasonable to posit the following rule.

(26) *Degemination*
$C_iC_i \rightarrow C_i$

The information notation "C_iC_i" means "two consonants with the same value".

Nasal deletion. The final process which applies to sequences of nasal plus consonant is one deleting a nasal before a voiceless fricative.

(27)

imperative	*3p. pres.*	*1s. pres*	*gloss*
fuma	βafuma	fuma	spread
fuundixa	βafuundixa	fuundixa	knot
fwa	βafwa	fwa	die
xala	βaxala	xala	cut
xalaaŋga	βaxalaaŋga	xalaaŋga	fry
xweesa	βaxweesa	xweesa	pull
seesa	βaseesa	seesa	winnow
siimbwa	βasiimbwa	siimbwa	have indigestion
somya	βasomya	somya	teach
sukuwa	βasukuwa	sukuwa	rub legs
sya	βasya	sya	grind

The predicted underlying form of "I spread" is /n-fuma/, which contains a sequence of nasal plus fricative. However, our data indicate that this sequence does not appear anywhere in the language, so we may presume that such sequences are eliminated by the following rule of nasal deletion.

(28) *Nasal deletion*
nasal $\rightarrow \varnothing$ / __ voiceless continuant

Summary. We have found in Bukusu that there are a number of phonological processes which affect N+C clusters, by voicing, hardening, or deleting the second consonant, or deleting the nasal before a nasal or a voiceless fricative.

(29) *Post-nasal voicing* (17)
voiceless → voiced / nasal ___

Nasal place assimilation (18)
$$\text{nasal} \rightarrow \alpha\text{place} \;/\; \_\_ \begin{bmatrix} \text{C} \\ \alpha\text{place} \end{bmatrix}$$

l-deletion (24)
l → ∅ / nasal __ V nasal

Post-nasal hardening (22)
voiced continuant → stop / nasal ___

Degemination (26)
$C_iC_i \rightarrow C_i$

Nasal deletion (28)
nasal → ∅ / __ voiceless continuant

Despite some similarity in these processes, in that they apply in the same general environment, there is no reasonable way to state these processes as one single rule.

In addition to showing how a complex system of phonological alternations decomposes into simpler, independent and partially intersecting rules, the preceding analyses reveal an important component of phonological analysis, which is observing regularities in data, such as the fact that Bukusu lacks any consonant sequences composed of a nasal plus a fricative on the surface. This raises the question how one is supposed to determine that such observations about data are empirically valid. The confidence with which such hypotheses can be made is a function of size of the database available for testing the hypothesis. If a corpus contains only one or two examples, it is hard to give any level of confidence to the correctness of any observations made from such a small corpus; on the other hand, if the available corpus contains tens of thousands of data points, a much higher level of confidence can be assigned to inferences about the language (provided that the datapoints are taken from various areas of the language: ten thousand examples of verbs in the past tense will tell you little about what will be seen in plural nouns). Even so, a hypothesis supported by tens of thousands of observations may be falsified by the next observation. We can only assert that it is increasing less likely that it will be falsified with a new observation.

After working for three years on Kikerewe, I only observed [b] after [m], and given the tens of thousands of available examples concluded that [b] only appears after a nasal. Three more years of research turned up four words with [b] not preceded by [m]. The initial hypothesis was falsified: but it was very unlikely that the hypothesis would be falsified.

This text is designed so that enough examples are provided that you can confidently make assertions about the structure of the language in question. Inevitably question may arise for which no data is available — for instance, consulting the data in (27), deletion of a nasal before [f] is only attested before the high round

vocoids [u,w]. One may then wonder whether nasal deletion would still take place with a hypothetical root such as *fala*. Since nasal deletion does apply to /n/ before the actual root /xala/ in "I cut", it is extremely unlikely that nasal deletion would fail before the hypothetical root [fala]. A definitive answer to this question requires a thorough search of the language.

1.5. Kimatuumbi

The following data from Kimatumbi illustrate the different surface realizations of the noun class prefixes (nouns are assigned lexically or syntactically to different classes, conventionally numbered between 1 and 21). What phonological rule applies in these examples?

(30)

Class	*C-initial noun*	*gloss*	*V-initial noun*	
4	mi-kaáte	'loaves'	my-oótó	'fires'
5	li-kuŋuúnda	'filtered beer'	ly-oowá	'beehive'
7	ki-kálaaŋgo	'frying pan'	ky-uúlá	'frog'
8	i-kálaaŋgo	'frying pans'	y-uúlá	'frogs'
14	u-tópe	'mud'	w-ɪ́mbɪ	'beer'
11	lu-toóndwa	'star'	lw-aaté	'banana hand'
13	tu-tóopé	'little handles'	tw-aána	'little children'
15	ku-suúle	'to school'	kw-iisíwá	'to the islands'
16	mu-kikú	'in the navel'	mw-iikú	'in the navels'

The examples in (31) illustrate one of the results of an optional rule deleting the vowel *u* after *m*, hence in these words, the prefix /mu/ can be pronounced in two ways, one with *u* and one without *u*. There is an independent rule in the language which assimilates a nasal to the place of articulation of the following consonant (we have seen that rule in previous Kimatuumbi data in Chapters 3 and 4). What other phonological process is illustrated by the following data?

(31)

unreduced form	*reduced form*	
mu-wesa...	ŋ-ŋ^{w}esa[3]	'you pl. can'
mu-wíkɪliile	ŋ-ŋ^{w}íkɪliile	'you pl. covered'
mu-yíkɪtiile	ñ-ñíkɪtiile	'you pl. agreed'
mu-yóyʊʊtite	ñ-ñóyʊʊtite	'you pl. whispered'
mu-wuúngo	ŋ-ŋ^{w}uungo	'in the civet'
mu-yɪíga	ñ-ñɪíga	'in the body'

[3] An alternative transcription of this form would be *ŋŋwesa*: the point of writing this as [ŋ^{w}] is to make clear that there is a change in the nature of the initial segment, and not the addition of another segment.

The examples in (32) illustrate the point that nouns which are in class 7 in the singular (which is marked with the prefix *ki*-) have their plural in class 8 (with the prefix *i*-). The plural locative form gives further illustration of a phonological process which has previously been motivated for the language, in this section.

(32)	*singular* (cl. 7)	*plural* (cl. 8)	*plural locative*	
	ki-báo	i-báo	mwii-báo	'stool'
	ki-bɩgá	i-bɩgá	mwii-bɩgá	'pot'
	ki-bíliítu	i-bíliitu	mwii-bíliitu	'box of matches'
	ki-bógoyó	i-bógoyó	mwii-bógoyó	'toothless person'

How do you explain the following examples of nouns, which also have singulars in class 7 and plurals in class 8, given that the class prefixes in these examples are underlyingly /ki-/ and /i/-?

(33)	*singular* (cl. 7)	*plural* (cl. 8)	*plural locative*	
	kyáaí	yáaí	muyáaí ~ ññáaí	soup pot
	kyaáka	yaáka	muyaáka ~ ññaáka	bush
	kyɩɩkí	yɩɩkí	muyɩɩkí ~ ññɩɩkí	stump
	kyuúbá	yuúbá	muyuúbá ~ ññuúbá	chest

2. Different Effects of Rule Ordering

Besides showing how greater generality can often be achieved by splitting a process into smaller pieces, these examples have illustrated that the application of one rule can brings into existence new environments where the second rule can apply, an environment which did not exist in the underlying form. What we observed happening in these cases was that both of the rules applied. Not all interactions between phonological processes are of this character, and in this section we consider some of the effects of different rule orderings.

2.1. Harmony and palatalization in Lamba

The following data illustrate the interaction between a rule of vowel harmony and a palatalization rule in the language Lamba.

(34)	*plain*	*passive*	*neuter*	*applied*	*reciprocal*	*gloss*
	čita	čitwa	čitika	čitila	čitana	'do'
	tula	tulwa	tulika	tulila	tulana	'dig'
	četa	četwa	četeka	četela	četana	'spy'
	soŋka	soŋkwa	soŋkeka	soŋkela	soŋkana	'pay tax'
	pata	patwa	patika	patila	patana	'scold'
	fisa	fiswa	fišika	fišila	fisana	'hide'

česa	česwa	česeka	česela	česana	'cut'
kosa	koswa	koseka	kosela	kosana	'be strong'
lasa	laswa	lašika	lašila	lasana	'wound'
masa	maswa	mašika	mašila	masana	'plaster'
šika	šikwa	šičika	šičila	šikana	'bury'
seka	sekwa	sekeka	sekela	sekana	'laugh at'
poka	pokwa	pokeka	pokela	pokana	'receive'
kaka	kakwa	kačika	kačila	kakana	'tie'
fuka	fukwa	fučika	fučila	fukana	'creep'

In order to see what these data show, we must first understand the morphological structure of these words is, a step which leads us to realise that the pronunciation of certain morphemes changes, depending on their phonetic context. Verbs in Lamba are composed of a root of the form CV(C)C, an optional derivational affix marking passive, neuter, applied or reciprocal, and a word-final suffix *-a* which marks the form as being a verb. The underlying forms of the passive and reciprocal suffixes are clearly *-w-* and *-an-*, since they exhibit no phonetic variations. The neuter and applied suffixes appear phonetically as *-ik-* and *-ek-*, *-il-* and *-el-*. The choice of vowel in the suffix is determined by the vowel which precedes the suffix: if the verb root contains the vowel *i, u* or *a* the suffix has the vowel *i*, and if the root contains the vowel *e* or *o* the suffix has the vowel *e*. The group of vowels *i, u, a* is not a natural phonetic class, so it is implausible that the suffixes are underlyingly *-el-* and *-ek-* with *-il-* and *-ik-* being derived by a rule. The class of vowels *e, o* is the phonetic class of mid vowels; it is thus evident that this language has a vowel harmony rule which assimilates underlying high vowels (in the suffixces /il/ and /ik/) to mid vowels when they are preceded by mid vowels.

(35) *Height harmony*
i → e / mid vowel ____

There is an alternation in the realization of certain root-final consonants. As shown in examples such as *kaka* ~ *kačika* and *lasa* ~ *lašika*, the velar consonants and the alveolar continuant *s* become alveopalatals when they are followed by the vowel *i*, by a process of palatalization.

(36) *Palatalization*
k,s → č, š / ___ i

The interaction between these processes is seen in words which could in principle undergo both of these processes: roots with the vowel *e* or *o*, and the final consonant *k* or *s*. The example *sekeka* 'laugh at' from /sek-ik-a/ shows how these processes interact. Suppose, first, that palatalization were to apply before vowel harmony. Since the underlying representation has the sequence /ki/ which is re-

quired by palatalization, that rule would apply. Subsequently, vowel harmony would assimilate /i/ to [e] after /e/, giving the wrong surface result. This is illustrated below in a derivation which spells out the results of applying first palatalization, then height harmony.

(37)	/sek-ik-a/	*underlying*
	sečika	*palatalization*
	*sečeka	*height harmony*

Thus, applying the rules in this order gives the wrong results: this order cannot be correct.

On the other hand, if we apply the processes in the other order, with height harmony applying before palatalization, then the correct form is generated.

(38)	/sek-ik-a/	*underlying*
	sekeka	*height harmony*
	(not applicable)	*palatalization*

In other words, by first applying vowel harmony, we are altering a property of the environment which is critical for palatalization — a front high vowel — by making the vowel become a mid vowel (which does not trigger palatalization in this language).

2.2. Voicing and epenthesis

Lithuanian. Another example which illustrates how an earlier rule can change a form in such a way that a later rule can no longer apply is found in Lithuanian. There is a process of voicing assimilation in Lithuanian whereby obstruents agree in voicing with an immediately following obstruent. This rule applies in the following examples to the verbal prefixes /at/ and /ap/.

(39)	a.	/at/	at-eiti	'to arrive'
			at-imti	'to take away'
			at-nešti	'to bring'
			at-leisti	'to forgive'
			at-likti	'to complete'
			at-ko:pti	'to rise'
			at-praši:ti	'to ask'
			at-kurti	'to reestablish'
		/ap/	ap-eiti	'to circumvent'
			ap-ieško:ti	'to search everywhere'
			ap-akti	'to become blind'
			ap-mo:ki:ti	'to train'

		ap-temd:ti	'to obscure'
		ap-šaukti	'to proclaim'
b.	/at/	ad-bekti	'to run up'
		ad-gauti	'to get back'
		ad-bukti	'to become blunt'
		ad-gimti	'to be born again'
	/ap/	ab-gauti	'to deceive'
		ab-žʸureti	'to have a look at'
		ab-želti	'to become overgrown'
		ab-dauži:ti	'to damage'
		ab-draski:ti	'to tear'

We would assume that the underlying forms of the prefixes are /at/ and /ap/, and that there is a rule which voices obstruents before voiced obstruents.

(40) *Voicing assimilation*
obstruent → voiced / ___ voiced obstruent

The alternative hypothesis would be that the prefixes are underlyingly /ad/ and /ab/. However, there is no natural context for describing the process of devoicing. Although devoicing of voiced obstruents before voiceless obstruents is quite natural, assuming that the prefixes have underlying voiced obstruents would also require the consonant to be devoiced before vowels and sonorant consonants, in order to account for the supposed derivations /ad-eiti/ → [ateiti], /ab-eiti/ → [apeiti], /ad-nešti/ → [atnešti] and /ab-mo:ki:ti/ → [apmo:ki:ti]. But there is clearly no constraint against voiced obstruents before vowels and sonorants in this language (in fact, no language has ever been attested with a rule of consonant devoicing where the conditioning environment is a following vowel). On the basis of this reasoning we conclude that the prefixes have underlying voiceless consonants.

When the initial consonant of the root is an alveolar stop, the vowel [i] appears after the prefix /at/, and similarly when the initial consonant is a bilabial stop, [i] is inserted after the consonant of /ap/.

(41)	ati-duoti	'to give back'
	ati-dari:ti	'to open'
	ati-deti	'to delay'
	ati-teisti	'to ajudicate'
	api-berti	'to strew all over'
	api-begti	'to run around'
	api-puti	'to grow rotten'

Given just the voicing assimilation rule, you would expect forms such as *[adduoti], *[abberti] by analogy to [adbekti] and [abdauži:ti]. Lithuanian does not allow sequences of identical consonants, so to prevent such a result, an epenthetic vowel is inserted between homorganic obstruent stops (which is notated in the rule by placing 'αplace' under each of the consonants).

(42) *Epenthesis*

$$\varnothing \rightarrow \text{i} \;/\; \underset{[\alpha\text{place}]}{\text{obstruent stop}} \;\_\_\_\; \underset{[\alpha\text{place}]}{\text{obstruent stop}}$$

The ordering of these rules is important: epenthesis (42) must apply before voicing assimilation, since otherwise the prefix consonant would assimilate the voicing of the root initial consonant and would then be separated from that consonant by the epenthetic vowel. The result of applying the voicing assimilation rule first would be to create [adduoti], [abberti], and then this would undergo vowel epenthesis to give incorrect *[adiduoti], *[abiberti]. If, on the other hand, epenthesis is the first rule applied, then underlying /at-duoti/ becomes [atiduoti] and /ap-berti/ becomes [apiberti]. Epenthesis eliminates the underlying cluster of obstruents, preventing the voicing rule from applying.

Armenian. Interestingly, a similar pair of rules exists in the New Julfa dialect of Armenian, but they apply in the opposite order. The 1 sg. future prefix is underlyingly *k*-, as shown in (43a), where the prefix is added to a vowel-initial stem. That /k/ assimilates voicing and aspiration from an obstruent which immediately follows it underlyingly (but not across a vowel). In addition, initial consonant clusters are broken up by an epenthetic schwa. As the data in (43b) show, the prefix consonant first assimilates to the initial consonant of the root, and then is separated from that consonant by schwa.

(43)

a.	k-ert^{h}am	'I will go'
	k-asiem	'I will say'
	k-aniem	'I will do'
	k-akaniem	'I will watch
	k-oxniem	'I will bless'
	k-urriem	'I will swell'
b.	kə-tam	'I will give'
	kə-kienam	'I will exist'
	gə-bəzzam	'I will buzz'
	gə-lam	'I will cry'
	gə-zəram	'I will bray'
	k^{h}ə-t^{h}uoγniem	'I will allow'
	k^{h}ə-č^{h}ap^{h}iem	'I will measure'

g^hə-b^hieřiem	'I will carry'
g^hə-g^huom	'I will come'
g^hə-d^{zh}ieviem	'I will form'

The difference between this dialect of Armenian and Lithuanian is that vowel epenthesis applies before consonant assimilation in Lithuanian but after that rule in Armenian, so that in Armenian both epenthesis and assimilation can apply to a given word, whereas in Lithuanian applying epenthesis to a word means that assimilation can no longer apply.

2.3. Lomongo: b-deletion and resolution of vowel hiatus

Sometimes, what needs to be remarked about the interaction between processes is the failure of one rule to apply to the output of another rule. This is illustrated in (44), (45) and (50) with examples from Lomongo. The first four examples demonstrate the shape of the various subject prefixes when they stand before a consonant

(44)

imp.	**1 sg.**	**2 sg.**	**3 sg.**	**1 pl.**	**2 pl.**	**3 pl.**	**gloss**
saŋga	nsaŋga	osaŋga	asaŋga	tosaŋga	losaŋga	basaŋga	say
kamba	ŋkamba	okamba	akamba	tokamba	lokamba	bakamba	work
mɛla	mmɛla	ɔmɛla	amɛla	tɔmɛla	lɔmɛla	bamɛla	drink
ǰila	nǰila	oǰila	aǰila	toǰila	loǰila	baǰila	wait

The underlying forms of the subject prefixes are /N/ (which stands for a nasal consonant, whose exact place of articulation cannot be determined), /o/, /a/, /to/, /lo/ and /ba/. There is a vowel harmony process assimilating the closed vowel /o/ to the open vowel [ɔ] when the following syllable contains either of the open vowels [ɛ] or [ɔ], and the prefix for 1 sg. subject assimilates in place of articulation to the following consonant.

The examples in (45) show how the subject prefixes are realized if the verb root begins with a vowel.

(45)

imp.	**1 sg.**	**2 sg.**	**3 sg.**	**1 pl.**	**2 pl.**	**3 pl.**	**gloss**
ɛna	nǰɛna	wɛna	ɛna	t^swɛna	ǰwɛna	bɛna	see
isa	nǰisa	wisa	isa	t^swisa	ǰwisa	bisa	hide
imeǰa	nǰimeǰa	wimeǰa	imeǰa	t^swimeǰa	ǰwimeǰa	bimeǰa	consent
usa	nǰusa	wusa	usa	t^swusa	ǰwusa	busa	throw
ina	nǰina	wina	ina	t^swina	ǰwina	bina	hate

When the 1s. subject prefix stands before the root, it has the shape [nǰ], which we will treat as being the result of insertion of [ǰ] between the prefix and a vowel initial root. (We might also assume the prefix /nǰ/, which simplifies before a conso-

nant, since such three-consonant sequences, viz. /nǰ-saŋga/, do not exist in the language).

(46) *Consonant prosthesis*
∅ → ǰ / n + __ V

The vowel /a/ deletes before another vowel, as shown by the 3 sg. and 3 pl. forms /a-ɛna/ → [ɛna] and /ba-ɛna/ → [bɛna].

(47) *Vowel truncation*
a → ∅ / ___ V

The prefixes /o/, /to/ and /lo/ undergo a process of glide formation where /o/ becomes [w] before a vowel.

(48) *Glide formation*
o → w / __ V

In the case of /to/ and /lo/ a further process affricates these consonants before a glide.

Turning /l/ into an affricate seem strange from a functional perspective, but is explained by the fact that *l* was originally /d/, so this rule comes historically from the more natural change /t,d/ → [t^s, d^z]/__i.

(49) *Affrication*
t,l → t^s,ǰ / ___ w

This affrication process must apply after glide formation, since it applies to a sequence of consonant plus glide that is created by the application of glide formation from an underlying consonant plus vowel sequence.

The final set of examples illustrate verb roots which underlyingly begin with the consonant /b/. As these data show, when underlying /b/ is preceded by a vowel, it is deleted.

(50)

imp.	**1 sg.**	**2 sg.**	**3 sg.**	**1 pl.**	**2 pl.**	**3 pl.**	**gloss**
bina	mbina	oina	aina	toina	loina	baina	dance
bota	mbota	oota	aota	toota	loota	baota	beget

Thus, surface [oina] derives from /obina/ and [baina] derives from /babina/, via the following rule.

(51) *Labial elision*
b → ∅ / V __ V

In this case, even though deletion of /b/ creates new sequences of *o*+V and *a*+V which could in principle undergo the rules of *a*-deletion and glide formation,

those rules do not in fact apply. In other words, in this case the grammar must contain some kind of explicit statement regarding the interaction of these processes, such as an explicit ordering of the rules, which guarantees that the output of *b*-deletion does not undergo glide-formation or *a*-deletion. By ordering the *b*-deletion rule so that it applies after the glide formation and vowel truncation rules, we explain why those two rules fail to apply, just in case the consonant *b* is deleted intervocalically. The ordering where *b*-deletion precedes vowel truncation and glide formation, illustrated in (52b), results in ungrammatical forms, which shows that that ordering of the rules is incorrect. ("NA" means that the rule cannot apply, because the conditions called for in the rule are not satisfied in the string).

(52)	a.	/o-bina/	/a-bina/	*underlying*
		NA	NA	*Glide Formation*
		NA	NA	*Vowel Truncation*
		oina	aina	*b-deletion*
	b.	/o-bina/	/a-bina/	*underlying*
		oina	aina	*b-deletion*
		wina	NA	*Glide Formation*
		NA	ina	*Vowel Truncation*
		*[wina]	*[ina]	

This is an example of the failure of a set of rules — especially vowel truncation and glide formation — to apply to the output of *b*-deletion.

2.4. Examples for discussion

Karok. These data from Karok illustrate three interacting phonological processes. Comment on the underlying forms of the following words, state what phonological rules are motivated, and discuss the order in which these processes apply.

(53)	*imperative*	*1 sg.*	*3 sg.*	
	pasip	nipasip	ʔupasip	'shoot'
	si:tva	niši:tva	ʔusi:tva	'steal'
	kifnuk	nikifnuk	ʔukifnuk	'stoop'
	suprih	nišuprih	ʔusuprih	'measure'
	ʔifik	niʔifik	ʔuʔifik	'pick up'
	ʔi:ftih	niʔi:ftih	ʔuʔi:ftih	'growing'
	ʔaktuv	niʔaktuv	ʔuʔaktuv	'pluck at'
	ʔakrap	niʔakrap	ʔuʔakrap	'slap'
	ʔarip	niʔarip	ʔuʔarip	'cut a strip'
	ʔaxyar	nixyar	ʔuxyar	'fill'
	ʔiškak	niškak	ʔuskak	'jump'

ʔimniš	nimniš	ʔumniš	‘cook’
ʔikšah	nikšah	ʔuksah	‘laugh’
ʔišriv	nišriv	ʔusriv	‘shoot at a target’

Shona. Often, a seemingly complex problem can be significantly simplified by breaking the problem up into a few interacting processes. If one looks at the phonetic realizations of the passive suffix in Shona, one will see that there are seven different manifestations of this suffix. However, this considerable range of variation can be explained in terms of a much smaller set of very general phonological rules, whose interaction results in many surface realizations of the suffix.

(54)

active	**passive**	**gloss**	**active**	**passive**	**gloss**
ɓika	ɓikwa	‘cook’	diba	dibɣa	‘dip’
p^{f}ugama	p^{f}ugamŋa	‘kneel’	pepa	pepxa	‘nurse’
ɓuɗa	ɓuɗɣwa	‘go out’	ruma	rumŋa	‘bite’
rova	rovɣa	‘stay away’	m̤aña	m̤añŋwa	‘run’
suŋga	suŋgwa	‘tie’	kwaša	kwašxwa	‘hunt’
teŋga	teŋgwa	‘buy’	fuŋga	fuŋgwa	‘think’
tamba	tambɣa	‘play’	b^{v}unza	b^{v}unzɣwa	‘ask’
imba	imbɣa	‘sing’	gara	garɣwa	‘stay’
set^{s}a	set^{s}xwa	‘amuse’	reḍ^{z}a	reḍ^{z}ɣwa	‘lengthen’
tapa	tapxa	‘capture’	βeza	βezɣwa	‘carve’
rega	regwa	‘leave’	ib^{v}a	ib^{v}ɣa	‘ripen’
šuža	šužɣwa	‘store grain’	taṣa	taṣxwa	‘ride’
peta	petxwa	‘fold’	dana	danŋwa	‘call’
ona	onŋwa	‘see’	ita	itxwa	‘do’
doka	dokwa	‘set’	seka	sekwa	‘laugh’
fesa	fesxwa	‘prick’	rasa	rasxwa	‘throw away’
raṇa	raṇŋwa	‘kick’	peṃa	peṃŋa	‘beg food’
goča	gočxwa	‘roast’	ṣika	ṣikwa	‘arrive’
d^{z}id^{z}a	d^{z}id^{z}ɣwa	‘learn’	fuka	fukwa	‘cover’
famba	fambɣa	‘walk’	nand^{z}a	nand^{z}ɣwa	‘lick’
gada	gadɣwa	‘mount’	ɓata	ɓatxwa	‘hold’
tuma	tumŋa	‘send’	tora	torɣwa	‘take’
oŋa	oŋwa	‘growl’	rima	rimŋa	‘plow’
sefa	sefxa	‘sieve’	kweẓa	kweẓɣwa	‘attract’
ǰuǰa	ǰuǰɣwa	‘leak’	guruva	guruvɣa	‘deceive’
maŋga	maŋgwa	‘arrest’	miña	miñŋwa	‘swallow’

The precise rules which you postulate will depend on what you assume to be the underlying form of the passive suffix, since there are two plausible underlying forms for the suffix, based on the data above. The phonological alternations seen in the following examples are relevant to deciding what the underlying form of the

passive suffix is (and therefore exactly how these phonological alternations are to be analyzed). These inflected forms involve a prefix marking the subject, followed by one of various tense markers such as *-ča-, -no-* and *-a-*, or no marker, finally followed by the verb stem.

(55) *subjunctive future*

urime	'that you sg. plow'	učarima	'you sg. will plow'
murime	'that you pl. plow'	mučarima	'you pl. will plow'
turime	'that they (tiny) plow'	tučarima	'they (tiny) will plow'
kunat^{s}e	'that there be nice'	kučanat^{s}a	'there will be nice'

habitual	*recent past*		
unorima	'you sg. plow'	warima	'you sg. plowed'
munorima	'you pl. plow'	mŋarima	'you pl. plowed'
tunorima	'they (tiny) plow'	txwarima	'they (tiny) plowed'
kunonat^{s}a	'there is nice'	kwanat^{s}a	'there was nice'

A further fact which is relevant to deciding on the correct analysis is that [γ], [x] do not appear after vowels or at the beginning of a word.

Klamath. The data in (56)-(60) from Klamath illustrate two processes. The first deaspirates and deglottalizes consonants before obstruents, before glottalized and voiceless resonants, as well as in word-final positions. The examples in (56) illustrate plain voiceless obstruents, which do not undergo any phonetic alternations. The data below involve a range of inflectionally and derivationally related word forms: the common root is underlined (the last form in this set also illustrates an alternation between *i* and *y*', which is not crucial).

(56)

la:**p**-a	'two (obj.)'	la:**p**	'two'
sk^{h}o**t**-a	'puts on a blanket'	sk^{h}o**t**-pli	'puts on a blanket again'
sʔa**p**-a	'tells'	sʔa**p**-s	'the telling'
q'la:**č**-aksi	'Blueberry Place'	q'la:**č**	'blueberry (sp.)'
wonč-am	'fir species'	wonč	'fir dugout canoe'
po**q**-a	'bakes camas'	po**q**-s	'camas root'
qle**k**-atk	'corpse'	qle**k**-s	'death'
mon**k**-am	'gopher's'	mon**k**	'gopher'
la**q**i	'is rich'	la**q**y'-a:ka	'little chief'

The data in (57) provide examples of underlyingly glottalized obstruents, which become plain voiceless consonants unless they are followed by a vowel or plain sonorant.

(57)	p’a**k’**-a	‘smashes’	p’a**k**-ska	‘chips off (intr.)’
	p’el**q’**-a	‘licks’	p’el**q**-papq’a	‘licks someone’s face’
			p’el**q**-ska	‘licks off’
	ʔe:**t’**-a	‘distributes’	se-ʔe:**t**-s	‘Saturday’
	poq-po**q’**-a	‘becomes dusty’	po:**q**-tki	‘becomes dusty’
	č^{h}a:**k’**-a	‘melts (intr)’	č^{h}a:**k**-tki	‘melts (as butter)’
	ʔi-č^{h}i:**č’**-a	‘makes shavings’	k-č^{h}i**č**-ta	‘scrapes ones foot on’
	č^{h}lo:**q’**-a	‘is smooth’	č^{h}lo:**q**-tki	‘becomes slick’
	k^{h}a-č’a:**q’**-a	‘mixes’	hoč-č’a**q**-t^{h}a	‘tangles self into a knot’
	n-qi:**č’**-att^{h}anʔa	‘is a tight fit on’	qi**č**-qič	‘tightly’
	qi**t’**-lqa	‘pours down’	qi**t**-q^{h}a	‘pours out’
	ɬo:**p’**-a	‘eats soup’	ɬo:**p**-s	‘soup’
	mpe-mpa**t’**-lqa	‘distrib. sinks’	mpe**t**-tqi	‘floats down’

Finally, the data in (58) show that aspirated consonants deaspirate in this same context.

(58)	li**č^h**-lič-l’i	‘strong’	li:**č**-tki	‘becomes strong’
	l’o-l’a**č^h**-lqa	‘kneels down’	l’o**č**-pka	‘is kneeling’
	ma**k^h**-lqa	‘sets up camp’	ma**k^h**-wal	‘camps on top of’
			ma**k**-pka	‘is camping’
	ponw-o:**t^h**-a	‘while drinking’	ponw-o:**t**-s	‘something to drink with’
	so:**č^h**-a	‘kindles a fire’	so:**č**-ti:la	‘lights a fire under’
	si:yo:**t^h**-a	‘trades pl. obj with each other’	si:yo:**t**-pli	‘trade back pl. obj’
	čo**q^h**-li:na	‘puts buttocks overboard’	čo**q**-paqpqa	‘holds buttocks in someone’s face’
	n’i**q^h**-o:wa	‘keeps putting’ a hand in water’	n’i**q**-tpa	‘reaches and touches’

The second process, a kind of syncope, deletes a short vowel from the first syllable of a stem when preceded by a CV prefix and followed by CV.

(59)	l**a**qi:ta	‘suspects s.o.’	sa-lqita	‘suspects each other
	m**a**č^{h}a:t-ka	‘listens’	sna-mč^{h}a:t-i:la	‘causes to hear’
			ma-mč^{h}a:t-i:la	‘dist. eavesdrop’
	m**e**č’a	‘moves camp’	me-mč’a	‘dist. moves’
	m**o**q’o:ka	‘mouse’	mo-mq’o:k-aʔa:k	‘dist. little mice’
	s**a**qo:tka	‘ask for s.t’	sa-sqo:tqa	‘dist. ask for s.t’
	s**i**čaq^{h}wa	‘wash hands’	hi-sčaq-t^{h}a	‘are angry with e.o’
	s**o**m	‘mouth’	so-sm’-a:k	‘dist. little mouths’
	s**o**m’alw’a	‘writes’	so-sm’alw’a	‘dist. writes’

What do the following examples show about the interaction of these two processes?

(60)	**q'o**č'a	'bends'	yo-**q**č'a	'bends with the feet'
	q^{h}ew'a	'breaks'	č^{h}e-**q**w'a	'sit on and break'
	t^{h}ew'a	'surface cracks'	ye-**t**w'a	'steps on and cracks surface'
	t^{h}it'a	'splits open a bulbous object'	č^{h}li-**t**t'a	'cuts open a bulbous object with a round object'
	s-**č'i**q'a	'squash with a pointed instrument'	yi-**č**q'a	'squash by pressure with the feet'
	n-**t'**el'a	'squashes with a round instrument'	swi-**t**l'a	'cinches'
	w-**k'a**l'a	'cuts with a long instrument'	kin-**k**l'a	'makes a mark with pointer'
	w-**p'e**q'a	'hits in the face with a long instrument'	hom-**p**q'a	'flies in the face'

Summary

Systems of phonological alternations in most languages involve a number of rules. This interaction means that one must discern the effects of individual rules, rather than subsume all alternations under one complex do-everything rule. A rule changes a given set of segments in a uniform manner, in a specified environment. So even when a language like Bukusu has a number of rules pertaining to sequences of nasal plus consonant — rules which have in common a single context NC — there may be quite a number of specific rules that apply in that context. Besides identifying what rules exist in a language, one must also determine what the proper ordering of those rules is. The correct order of a pair of rules can be determined by applying the rules very literal-mindedly in both of the logically possible orders.

Exercises

1: Kerewe

What two rules are motivated by the following data; explain what order the rules apply in.

to V	*to V e.o*	*to V for*	*to V for e.o*	
kubala	kubalana	kubalila	kubalilana	"count"
kugaya	kugayana	kugayila	kugayilana	"despise"
kugula	kugulana	kugulila	kugulilana	"buy"
kubála	kubálána	kubálíla	kubálílana	"kick"
kulúma	kulúmána	kulúmíla	kulúmílana	"bite"
kusúna	kusúnána	kusúníla	kusúnílana	"pinch"
kulába	kulábána	kulábíla	kulábílana	"pass"

to V us	*to V it*	*to V for us*	*to V it for us*	
kutúbála	kučíbála	kutúbálila	kučítúbalila	"count"
kutúgáya	kučígáya	kutúgáyila	kučítúgayila	"despise"
kutúgúla	kučígúla	kutúgúlila	kučítúgulila	"buy"
kutúbála	kučíbála	kutúbálila	kučítúbalila	"kick"
kutúlúma	kučílúma	kutúlúmila	kučítúlumila	"bite"
kutúsúna	kučísúna	kutúsúnila	kučítúsunila	"pinch"
kutúlába	kučílába	kutúlábila	kučítúlabila	"pass"

2: Polish

What phonological rules are motivated by the following examples, and what order do those rules apply in?

singular	*plural*		*singular*	*plural*	
klup	klubi	'club'	trup	trupi	'corpse'
dom	domi	'house'	snop	snopi	'sheaf'
žwup	žwobi	'crib'	trut	trudi	'labor'
dzvon	dzvoni	'bell'	kot	koti	'cat'
lut	lodi	'ice'	grus	gruzi	'rubble'
nos	nosi	'nose'	vus	vozi	'cart'
wuk	wugi	'lye'	wuk	wuki	'bow'
sok	soki	'juice'	ruk	rogi	'horn'
bur	bori	'forest'	vuw	vowi	'ox'
sul	soli	'salt'	buy	boyi	'fight'
šum	šumi	'noise'	žur	žuri	'soup'

2: Ancient Greek

Discuss the phonological rules and underlying representations which are necessary to account for the following nouns; comment on the ordering of these phonological processes.

nom. sg.	*gen. sg.*	*dat. sg*	*dat. pl.*	
hals	halos	hali	halsi	‘salt’
oys	oyos	oyi	oysi	‘sheep’
sus	suos	sui	susi	‘sow’
klo:ps	klo:pos	klo:pi	klo:psi	‘thief’
p^{h}le:ps	p^{h}le:bos	p^{h}le:bi	p^{h}le:psi	‘vein’
kate:lips	kate:lip^{h}os	kate:lip^{h}i	kate:lipsi	‘upper story’
p^{h}ulaks	p^{h}ulakos	p^{h}ulaki	p^{h}ulaksi	‘guard’
ayks	aygos	aygi	ayksi	‘goat’
salpiŋks	salpiŋgos	salpiŋgi	salpiŋksi	‘trumpet’
onuks	onuk^{h}os	onuk^{h}i	onuksi	‘nail’
t^{h}e:s	t^{h}e:tos	t^{h}e:ti	t^{h}e:si	‘serf’
k^{h}aris	k^{h}aritos	k^{h}ariti	k^{h}arisi	‘grace’
elpis	elpidos	elpidi	elpisi	‘hope’
korus	korut^{h}os	korut^{h}i	korusi	‘helmet’
ri:s	ri:nos	ri:ni	ri:si	‘nose’
delp^{h}i:s	delp^{h}i:nos	delp^{h}i:ni	delp^{h}i:si	‘porpoise’

3: Shona

In the following examples, vowels marked with an accute accent have a H tone and those without an accent have a L tone. Comparing the two sets of data immediately below, what tone rule do the following data motivate? In the examples below, one will notice alternations in the form of adjectives, e.g. *kurefū, karefū, marefū* all meaning “long”. Adjectives have an agreement prefix, hence *kurefū* marks the form of the adjective in one grammatical class, and so on. In some cases, the agreement is realized purely as a change in the initial consonant of the adjective, i.e. *gúrú ~ kúrú ~ húrú* which need not be explained.

guɗo	‘baboon’	guɗo gúrú	‘big baboon’
bveni	‘baboon’	bveni pfúpi	‘short baboon’
táfura	‘table’	táfura húrú	‘big table’
tsamba	‘letter’	tsamba čéna	‘clean letter’
ŋombe	‘cow’	ŋombe húrú	‘big cow’
šoko	‘word’	šoko bvúpi	‘short word’
ɓadzá	‘hoe’	ɓadzá gúrú	‘big hoe’
zigómaná	‘boy (aug.)’	zigómaná gúrú	‘big boy (aug.)’
imbá	‘house’	imbá čéna	‘clean house’
nuŋgú	‘porcupine’	nuŋgú pfúpi	‘short porcupine’
mhará	‘gazelle’	mhará čéna	‘clean gazelle’
ndzizí	‘rivers’	ndzizí pfúpi	‘short rivers’
marí	‘money’	marí čéna	‘clean money’

ɓáŋgá	‘knife’	ɓáŋga gúrú	‘big knife’
ɗémó	‘axe’	ɗémo bvúpi	‘short axe’
nhúmé	‘messenger’	nhúme pfúpi	‘short messenger’
húní	‘firewood’	húni pfúpi	‘short firewood’
ǰírá	‘cloth’	ǰíra ǰéna	‘clean cloth’
bvéní	‘it’s a baboon’	bvéni gúrú	‘it’s a big baboon’
hárí	‘pot’	hári húrú	‘big pot’
mbúndúdzí	‘worms’	mbúndúdzi húrú	‘big worms’
búku	‘book’	búku gúrú	‘big book’
fúma	‘wealth’	fúma čéna	‘clean wealth’
nyíka	‘country’	nyíka húrú	‘big country’
hákáta	‘bones’	hákáta pfúpi	‘short bones’
ǰékéra	‘pumpkin’	ǰékéra gúrú	‘big pumpkin’

These data provide further illustration of the operation of this tone rule.

guɗo	‘baboon’	gudo rákafá	‘the baboon died’
tsamba	‘letter’	tsamba yákawá	‘the letter fell’
ɓadzá	‘hoe’	ɓadzá rákawá	‘the hoe fell’
nuŋgú	‘porcupine’	nuŋgú yákafá	‘the porcupine died’
marí	‘money’	marí yákawá	‘the money fell’
ɓáŋgá	‘knife’	ɓáŋga rákawá	‘the knife fell’
nhúmé	‘messenger’	nhúme yákafá	‘the messenger died’
hárí	‘pot’	hári yákawá	‘the pot fell’
mbúndúdzí	‘worms’	mbúndúdzi yákafá	‘the worms fell’
búku	‘book’	búku rákawá	‘the book died’
hákáta	‘bones’	hákáta yákawá	‘the bones fell’
mapfeni	‘baboons’	mapfeni makúrú	‘big baboons’
mašoko	‘words’	mašoko mažíǰí	‘many words’
mapadzá	‘hoes’	mapadzá makúrú	‘big hoes’
mukómaná	‘boy’	mukómaná mupfúpi	‘short boy’
mapáŋgá	‘knives’	mapáŋgá makúrú	‘big knives’
nhúmé	‘messenger’	nhúmé ndefú	‘short messenger’
matémó	‘axes’	matémó mapfúpi	‘short axes’
kahárí	‘pot (dim.)’	kahárí kačéna	‘clean pot (dim.)’
mabúku	‘books’	mabúku mažíǰí	‘many books’
kunyíka	‘to the land’	kunyíka kukúrú	‘to the big land’
čitóro	‘store’	čitóro čikúrú	‘big store’

In the examples below, a second tone rule can be seen to operate.

guɗo	‘baboon’	guɗo refú	‘tall baboon’
šoko	‘word’	šoko refú	‘long word’

búku	‘book’	búku refú	‘long book’
nyíka	‘country’	nyíka refú	‘long country’
badzá	‘hoe’	badzá refú	‘long hoe’
nuŋgú	‘porcupine’	nuŋgú ndefú	‘long porcupine’
mhará	‘gazelle’	mhará ndefú	‘tall gazelle’
makuɗo	‘baboons’	makuɗo marefú	‘tall baboons’
mašoko	‘words’	mašoko marefú	‘long words’
búku	‘book’	búku refú	‘long book’
kunyíka	‘to the land’	kunyíka kurefú	‘to the long land’
mapadzá	‘hoes’	mapadzá márefú	‘long hoes’
kamhará	‘gazelle (dim.)’	kamhará kárefú	‘long gazelle (dim.)’
kanuŋgú	‘porcupine (dim.)’	kanuŋgú kárefú	‘long porcupine (dim)’

The next set of data provide further examples of that tone rule applying.

guɗo	‘baboon’	guɗo gobvú	‘thick baboon’
búku	‘book’	búku kobvú	‘thick book’
ɓadzá	‘hoe’	ɓadzá gobvú	‘thick hoe’
nuŋgú	‘porcupine’	nuŋgú hobvú	‘thick porcupine’
makuɗo	‘baboons’	makuɗo makobvú	‘thick baboons’
búku	‘book’	búku gobvú	‘thick book’
mapadzá	‘hoes’	mapadzá mákobvú	‘thick hoes’
tsamba	‘letter’	tsamba nhete	‘thin letter’
ŋombe	‘cow’	ŋombe nhete	‘thin cow’
búku	‘book’	búku ɗete	‘thin book’
hákáta	‘bones’	hákáta nhete	‘thin bones’
ɓadzá	‘hoe’	badzá ɗéte	‘thin hoe’
imbá	‘house’	imbá nhéte	‘thin house’
ndzizí	‘rivers’	ndzizí nhéte	‘thin rivers’

What do the following examples show about these tone rules?

ɓáŋgá	‘knife’	ɓáŋgá ɗéte	‘thin knife’
ɗémó	‘axe’	démó ɗéte	‘thin axe’
murúmé	‘person’	murúmé mútete	‘thin person’
kahúní	‘firewood (dim.)’	kahúní kárefú	‘long firewood’
mačírá	‘clothes’	mačírá márefú	‘long clothes’
hárí	‘pot’	hárí nhéte	‘thin pot’

4: Catalan

Give phonological rules which account for the following data, and indicate what ordering is necessary between these rules. For each adjective stem, state what the

underlying form of the root is. Pay attention to the difference between surface [b,d,g] and [β,ð,γ], in terms of predictability.

masc sing.	*fem sing.*		*masc sing.*	*fem sing.*	
əkel^{y}	əkel^{y}ə	'that'	mal	malə	'bad'
siβil	siβilə	'civil'	əskerp	əskerpə	'shy'
šop	šopə	'drenched'	sɛk	sɛkə	'dry'
əspɛs	əspɛsə	'thick'	gros	grosə	'large'
baš	bašə	'short'	koš	košə	'lame'
tot	totə	'all'	brut	brutə	'dirty'
pɔk	pɔkə	'little'	prəsis	prəsizə	'precise'
frənses	frənsezə	'French'	gris	grizə	'grey'
kəzat	kəzaðə	'married'	bwit	bwiðə	'empty'
rɔč	rɔžə	'red'	boč	božə	'crazy'
orp	orβə	'blind'	l^{y}ark	l^{y}arγə	'long'
sek	seγə	'blind'	fəšuk	fəšuγə	'heavy'
grok	groγə	'yellow'	puruk	puruγə	'fearful'
kandit	kandiðə	'candid'	frɛt	frɛðə	'cold'
səγu	səγurə	'sure'	du	durə	'hard'
səγəðo	səγəðorə	'reaper'	kla	klarə	'clear'
nu	nuə	'nude'	kru	kruə	'raw'
sa	sanə	'healthy'	pla	planə	'level'
bo	bonə	'good'	sərɛ	sərɛnə	'calm'
suβlim	suβlimə	'sublime'	al	altə	'tall'
fɔr	fɔrtə	'strong'	kur	kurtə	'short'
sor	sorðə	'deaf'	bɛr	bɛrðə	'green'
san	santə	'saint'	kəlɛn	kəlɛntə	'hot'
prufun	prufundə	'deep'	fəkun	fəkundə	'fertile'
dəsen	dəsentə	'decent'	dulen	dulentə	'bad'
əstuðian	əstuðiantə	'student'	blaŋ	blaŋkə	'white'

5: Finnish

Propose rules which will account for the following alternations. It would be best not to write a lot of rules which go directly from underlying forms to surface forms in one step; instead, propose a sequence of rules whose combined effect brings about the change in the underlying form.

genitive sing.	*nom. sing.*	*nom. pl.*	*ablative sing.*	*essive sing.*	*gloss*
kanadan	kanada	kanadat	kanadalta	kanadana	Canada
kiryan	kirya	kiryat	kiryalta	kiryana	book
aamun	aamu	aamut	aamulta	aamuna	morning

talon	talo	talot	talolta	talona	house
koiran	koira	koirat	koiralta	koirana	dog
hüvæn	hüvæ	hüvæt	hüvæltæ	hüvænæ	good
kuvan	kuva	kuvat	kuvalta	kuvana	picture
lain	laki	lait	lailta	lakina	roof
nælæn	nælkæ	nælæt	nælæltæ	nælkænæ	hunger
yalan	yalka	yalat	yalalta	yalkana	leg
leuan	leuka	leuat	leualta	leukana	chin
paran	parka	parat	paralta	parkana	poor
reiæn	reikæ	reiæt	reiæltæ	reikænæ	hole
nahan	nahka	nahat	nahalta	nahkana	hide
vihon	vihko	vihot	viholta	vihkona	notebook
laihan	laiha	laihat	laihalta	laihana	lean
avun	apu	avut	avulta	apuna	help
halvan	halpa	halvat	halvalta	halpana	cheap
orvon	orpo	orvot	orvolta	orpona	orphan
leivæn	leipæ	leivæt	leivæltæ	leipænæ	bread
pæivæn	pæivæ	pæivæt	pæivæltæ	pæivænæ	day
kilvan	kilpa	kilvat	kilvalta	kilpana	competition
külvün	külpü	külvüt	külvültæ	külpünæ	bath
tavan	tapa	tavat	tavalta	tapana	manner
korvan	korva	korvat	korvalta	korvana	ear
æidin	æiti	æidit	æiditæ	æitinæ	mother
kodin	koti	kodit	kodilta	kotina	home
muodon	muoto	muodot	muodolta	muotona	form
tædin	tæti	tædit	tæditæ	tætinæ	aunt
kadun	katu	kadut	kadulta	katuna	street
maidon	maito	maidot	maidolta	maitona	milk
pöüdæn	pöütæ	pöüdæt	pöüdæltæ	pöütænæ	table
tehdün	tehtü	tehdüt	tehdültæ	tehtünæ	made
læmmön	læmpö	læmmöt	læmmöltæ	læmpönæ	warmth
laŋŋan	laŋka	laŋŋat	laŋŋalta	laŋkana	thread
sæŋŋün	sæŋkü	sæŋŋüt	sæŋŋültæ	sæŋkünæ	bed
hinnan	hinta	hinnat	hinnalta	hintana	price
linnun	lintu	linnut	linnulta	lintuna	bird
opinnon	opinto	opinnot	opinnolta	opintona	study
rannan	ranta	rannat	rannalta	rantana	shore
luonnon	luonto	luonnot	luonnolta	luontona	nature
punnan	punta	punnat	punnalta	puntana	pound
tunnin	tunti	tunnit	tunnilta	tuntina	hour
kunnon	kunto	kunnot	kunnolta	kuntona	condition
kannun	kannu	kannut	kannulta	kannuna	can
linnan	linna	linnat	linnalta	linnana	castle

tumman	tumma	tummat	tummalta	tummana	dark
auriŋŋon	auriŋko	auriŋŋot	auriŋŋolta	auriŋkona	sun
reŋŋin	reŋki	reŋŋit	reŋŋiltæ	reŋkinæ	farm hand
vaŋŋin	vaŋki	vaŋŋit	vaŋŋilta	vaŋkina	prisoner
kellon	kello	kellot	kellolta	kellona	watch
kellan	kelta	kellat	kellalta	keltana	yellow
sillan	silta	sillat	sillalta	siltana	bridge
kullan	kulta	kullat	kullalta	kultana	gold
virran	virta	virrat	virralta	virtana	stream
parran	parta	parrat	parralta	partana	beard

6: Korean

Provide rules which will account for the alternations in the stem final consonant in the following examples. State what underlying representation you are assuming for each noun.

‘rice’	‘forest’	‘chestnut’	
pamman	summan	pamman	only N
pammaŋk^{h}ɨm	summaŋk^{h}ɨm	pammaŋk^{h}ɨm	as much as N
pamnaɨm	sumnaɨm	pamnaɨm	depending on N
pap	sup	pam	N
papt’ero	supt’ero	pamtero	like N
papk’wa	supk’wa	pamkwa	with N
papp’ota	supp’ota	pampota	more than N
papk’ači	supk’ači	pamk’ači	until N
papi	sup^{h}i	pami	N (nominative)
papɨn	sup^{h}ɨn	pamɨn	N (topic)
pape	sup^{h}e	pame	to N
papita	sup^{h}ita	pamita	it is N
papɨro	sup^{h}ɨro	pamɨro	using N

‘field’	‘sickle’	‘day’	
pamman	namman	namman	only N
pammaŋk^{h}ɨm	nammaŋk^{h}ɨm	nammaŋk^{h}ɨm	as much as N
pannaɨm	nannaɨm	nannaɨm	depending on N
pat	nat	nat	N
patt’ero	natt’ero	natt’ero	like N
pakk’wa	nakk’wa	nakk’wa	with N
papp’ota	napp’ota	napp’ota	more than N
pakk’ači	nakk’ači	nakk’ači	until N
pač^{h}i	nasi	načі	N (nominative)
pat^{h}ɨn	nasɨn	načɨn	N (topic)
pat^{h}e	nase	nače	to N

pač^{h}ita	nasita	načita	it is N
pat^{h}-iro	nas-iro	nač-iro	using N

'face'	'half'	
namman	pamman	only N
nammaŋk^{h}-im	pammaŋk^{h}-im	as much as N
nannar-im	pannar-im	depending on N
nat	pan	N
natt'ero	pantero	like N
nakk'wa	paŋkwa	with N
napp'ota	pampota	more than N
nakk'ači	paŋk'ači	until N
nač^{h}i	pani	N (nominative)
nač^{h}-in	pan-in	N (topic)
nač^{h}e	pane	to N
nač^{h}ita	panita	it is N
nač^{h}-iro	pan-iro	using N

Advanced Topics and Readings

For the typical American Structuralist, a description of a language states relations between levels of analysis, so phonetic [p^{h}] in English relates to the phoneme /p/, which may relate to a morphophoneme ||p|| and so on. Unlike the generative approach, the taxonomic approach does not have intermediate stages in a derivation except by having certain prespecified levels (the surface, phonemic, and morphophonemic levels), and thus all generalization (rules, in a sense) hold simultaneously — they are stated as "time-invariant" true statements about the relation between what are claimed to be the significant levels of analysis. Still, the efficacy of ordered rules was recognised in a few structuralist analyses, for example Bloomfield in his analysis of Menomini (Bloomfield 1939) who says "If one starts with the basic forms and applies our statements (§§10 and following) in the order in which we give them, one will arrive finally at the forms of words as they are actually spoken". See Bever 1967 for discussion of the similarities between Bloomfield's description of Menomini and the theory of generative phonology, and Kenstowicz 1977 for an overview of pre-generative views on rule ordering.

The formal character of rule ordering in generative phonology is stated in Chomsky & Halle 1968 as a ordered list (analogous to the integers *1, 2, 3, 4..*), specifically as a linear order, a technical concept discussed in detail in Wall 1972. A strong linear ordering of the form (A, B, C, D...) observes four formal conditions. First, it is transitive: if A precedes B and B precedes C, then A precedes C. Second: it is irreflexive: no rule precedes itself. Third, it is asymmetric: if A precedes B then B cannot precede A. Finally, the rules have the property of connexity, meaning that all rules are ordered — either A precedes B or B precedes A, and no

rules are unordered, and no two rules can apply simultaneously. Rules apply Markovianly, meaning that a rule only has access to the form of a phonological string as it exists when the rule applies: the first rule sees only the underlying form, the second rule only sees the output of the first rule, and so on.

One part of this characterization of a grammar was challenged early in generative phonology, that a rule may not precede itself. This assumption proved incorrect, since it prevents rules from applying to successive strings of segments. A typical problem case is vowel harmony, exemplified by the rule of Yawelmani which rounds a vowel after a round vowel if the vowels agree in height, whereby /hubiṣmixhin/ first becomes *hubuṣmixhin*, then *hubuṣmuxhin* and finally [hubuṣmuxhun] "choose (aorist comitative)", reapplying harmony to its own output, working from left to right through the string (compare /hubiṣtaw/ which becomes [hubuṣtaw] "choose (nondirective gerundial)", which rounds only the first vowel because the vowel *a* is not of the same height as *u*).

Chomsky & Halle 1968 propose a special formalism to handle this, the star-parenthesis variable notation which in the case of Yawelmani harmony allowed consonants and vowels of the same height to be skipped over. However, Johnson 1972, Howard 1972, Anderson 1974, Phelps 1975, Kenstowicz & Kisseberth 1977, inter alii, pointed to a number of problems with that mechanism: the essence of the problem is that the material contained in star-parenthesis noncoincidentally repeats the description of the vowels which will undergo the rule. An alternative theory, the iterative theory,[4] was proposed to the effect that rules always apply to their own output, beginning at one end of a string, and the rule reapplies moving one segment at a time until it reaches the opposite end of the string (hence, rule ordering is seen as a total, weak order, replacing the irreflexivity condition with a reflexivity condition). See especially Howard 1972, Jensen & Stong-Jensen 1973, Battistella 1979 and Vago & Battistella 1982 on the topic of predicting the direction in which rules apply.

Another proposal relevant to rule interaction is the Elsewhere Condition, proposed by Kiparsky 1972 (a principle also employed in the ancient Sanskrit grammatical tradition). This condition deals with the relationship between two rules A, B, which are so similar that any string that could undergo A can also undergo B — but not vice versa. If the changes performed by the rules are either the same or are mutually incompatible, the "more specific" rule which applies to fewer forms must have precedence over the "more general" or "elsewhere" rule, which applies to the larger set of words. This then imposes an ordering on the rules.

Another modification to the concept of strict linear ordering is the cycle — we have not seen this mode of rule application so far. Cyclic application results in the situation where two rules apply in the order A > B, but in the course of a deri-

[4] Johnson 1972 adheres to an important mathematical terminological distinction between *iterative* rules and *linear* rules, the latter being the kinds of rules which are commonly called "iterative" in phonological theory.

vation one finds rule applications of the type A, then B, then A; or, A followed by an application of A, but in a manner that cannot be subsumed under the concept of rule iteration. By themselves, such examples would be serious ordering paradoxes. An example is the interaction between u-umlaut and syncope in Icelandic. The first changes /a/ to [ö] before *u*, so /bagg+ul/ becomes [böggul] "package (acc. sg)". The underlying quality of the initial vowel is motivated by *bagg-i* "pack". Syncope deletes a non-initial vowel in an open syllable, whereby /hamar+i/ becomes [hamri] "hammer (dat. sg)". The fact that /katil+um/ becomes [kötlum] "kettle (dat. pl)" demonstrates that Syncope precedes *u*-umlaut — it eliminates the vowel that triggers *u*-umlaut. However, underlying /bagg+ul+i/ becomes [böggli] "package (dat. sg)", which can only be explained by applying *u*-umlaut first, then Syncope. Thus we have the paradox that Syncope precedes *u*-umlaut but *u*-umlaut precedes Syncope.

Applying these rules cyclically removes the paradox, by exploiting the fact that the underlying forms /bagg-ul-i/ and /katil-um/ differ in morphological constituencies — [[bagg-ul]-i] vs. [katil-um], the former involving a monosyllabic root plus a derivational affix, the latter having a disyllabic root. With cyclic rule application, Syncope precedes *u*-umlaut. These rules apply to the smallest substring which has no internal brackets, thus, they apply to *bagg-ul* and *katil-um* respectively. Under the ordering Syncope > *u*-umlaut, the form *katilum* is first derived. Both forms then undergo *u*-umlaut, giving *böggul* and *kötlum* at the end of the first cycle of rule application. Then the internal brackets are removed, resulting in *böggul-i*, which is again subjected to the rules of the phonology, allowing Syncope to apply giving [böggli]. Strict linear ordering holds for each part of a derivation corresponding to the material within a cyclic domain.

The earliest examples of the cycle were for stress assignment, both phrasal stress and word-level stress — see Chomsky & Halle 1968 — and it was often assumed at that point that only stress rules were cyclic. Further arguments for the cycle are found in Kisseberth 1971, Kaye & Piggott 1973, Brame 1974, Kean 1974, Mascaro 1976, and Rubach 1984 inter alii. Cole 1995 overviews a number of theoretical issues relevant to the phonological cycle. Having rules that apply cyclically raises two fundamental questions: what defines the domain of a cycle, and which rules are cyclic? The model of Lexical Phonology (Kiparsky 1982 and others) provides a mechanism for automatically deriving the cycle, via that theory's interaction between phonology and morphology where a form is resubmitted to the phonology. It also offers a partial answer to the question of which rules are cyclic: only lexical rules may be cyclic (however, not all lexical rules are cyclic, see for example Rubach 1990).

Kiparsky 1968 defines four fundamental relations which have played a central role in discussions of ordering. One, termed **feeding**, arises when A precedes B and application of A creates new strings that can undergo B, which would not have existed except by applying the first rule A. Glide Formation in Kikamba (section 1.3) turns *e* into *y* before a vowel, and palatalization changes *ky* into *č*.

Glide Formation creates instances of *y* not underlyingly present, and derived *y* conditions the palatalization rule: /kokéấsyấ/ first becomes *kokyấấsyấ*, then [kočấấsyấ] by palatalization, conditioned by this derived *y*. **Counterfeeding** is where A precedes B, and the output of B satisfies the requirements of A, but rule A does *not* apply to the output of rule B. An example of that relation is Lomongo (section 2.3), where *b*-deletion deletes *b* between vowels, and *o* before another vowel becomes *w*. However, the sequence *oi* brought into existence by *b*-deletion does not undergo Glide Formation, so /obina/ surfaces as [oina], not *[wina]: *b*-deletion counterfeeds Glide Formation.

A **bleeding** relation is where the input to rule A could undergo both A and B, but the output of A can no longer undergo rule B — applying A destroys the structure necessary for B. This mode of application is illustrated in 2.2 with Lithuanian, where Epenthesis and Voicing Assimilation could both apply to underlying /at-duoti/, but in fact epenthesis applies first to give *atiduoti*, so the epenthetic vowel makes it impossible for voicing assimilation to apply. The opposite relation, **counterbleeding**, is found in Armenian, where an obstruent first assimilates to the following consonant in voicing and aspiration so /k-b^{h}ieřiem/ becomes *g^h-b^{h}ieřiem,* but the consonants are then separated by epenthesis giving [g^{h}ə-b^{h}ieřiem] 'I will carry'. Counterbleeeding can be defined negatively as "if the rules were in the opposite order, the relation would be bleeding".

Rule ordering has been considered to be a powerful descriptive device, one that allows perhaps too many languages to be theoretically describable. If a language has 5 rules, how many ways can those rules be ordered? Mathematical combinatorics provides 5! (5×4×3×2×1) = 120 possible permutations of just 5 rules, and over 87 billion arrangements of 14 rules. The ability to arrange rules in any permutation thus allows a huge number of grammars to be described, resulting in a considerable disparity between descriptive potential and actual languages.

One approach to this problem is to limit rule ordering. Since the theory of strict ordering requires all rules to be placed in a specific order, perhaps a solution is to let some rules be unordered (see Chomsky 1967). A partial ordering is one where not all pairs of rules have to be ordered, and thus some two rules A and B might be unordered. Taken by itself, this actually makes the problem vastly worse. Whereas only 120 arrangements of 5 rules are allowed when rules are totally ordered, 4,231 orders are possible under partial ordering. While the number of strict orders of 14 rules is very large — over 87 billion — the number of partial orders of 14 rules is over a trillion times larger (98,484,324,257,128,207,032,183: the number of partial orderings for sets larger than 14 has not been computed). Thus, partial ordering of rules is much worse than strict ordering, in terms of providing too many ways to construct a grammar.

The Unordered Rule Hypothesis of Koutsoudas, Sanders & Noll 1974 and subsequent work argues that a grammar needs no extrinsic ordering statements. All rules apply simulaneously to a string, and the results are continuously resubmitted to the phonology until no more rules are applicable. Various principles of rule

application are needed in this theory to guarantee corrects results, for example the Proper Inclusion Precedence Principle (very similar to the Elsewhere Condition of Kiparsky 1972) which states that when a specific rule and a general rule can both apply to a string and the change performed by one rule is incompatible with the change performed by the other rule, the specific rule takes precedence over the general rule. This model easily achieves the effect of a feeding rule ordering without any specific ordering relation being imposed on the rules by dint of the fact that rules reapply until they can no longer apply. Thus the fact that Glide Formation in Kikamba feeds Palatalization is handled by simply applying all rules possible to /kokéấsyấ/ which gives *kokyấấsyấ* — only Glide Formation happens to be applicable — and reapplying all rules to that output — only Palatalization happens to be applicable — giving [kočấấsyấ], which cannot unergo any further rules. This theory fails to handle counterfeeding relationships such as that in Lomongo where /o-ina/ becomes [wina] but /obina/ becomes [oina] and not *[wina]. See Trommelen & Zonneveld 1978 for critical discussion of the Unordered Rule Hypothesis.

Other proposals for rule interaction include the theory of Local Ordering (Anderson 1974); Two-level phonology (Koskeniemi 1983, Kartunen 1993), and especially Harmonic Phonology (Goldsmith 1993) which includes both a reapplicative component within a level that allows an account of feeding relations, and a single-step mapping between levels, which enables counter-feeding relations to be captures.

Optimality Theory approaches the issue differently: because OT has no rules, there can be no rule ordering. The theory more closely resembles the Direct Mapping Hypothesis of Kenstowicz & Kisseberth 1978, since there are no intermediate steps between the underlying and surface forms. In OT, a surface form is selected directly, by reference to the relationship between the underlying form and the surface form, with respect to a set of constraints that are evaluated in a particular order to be specified for the language. OT still requires a combinatoric device with the permutational possibilities found with rule ordering, in the form of constraint ranking — a grammar in OT is seen as a set of ranked (ordered) constraints, so we face the question of possible permutations, in this case, permutations of the set of constraints. However, derivationally intermediate forms are not part of an OT account. Kiparsky 2000 proposes a hybrid model of Lexical Phonology and Optimality theory, along lines conjectured by McCarthy & Prince 1993 for Axininca Campa and other places in the OT literature, where a phonology has ordered levels, but the content of each level is a single input-to-output mapping as typically assumed for OT.

6

Feature Theory

This chapter explores the theory of representing language sounds as symbolic units. You will:

- see that sounds are defined in terms of a fixed set of universal features
- learn the phonetic definitions of features, and how to assign feature values to segments based on phonetic properties
- understand how phonological rules are formalised in terms of those features
- see how these features makes predictions about possible sounds and rules in human language

The discussion of sound systems has been conducted without attention to what sounds are made of, as cognitive units. We have simply treated them as letters, labeled by traditional articulatory descriptions. It is time now to raise a fundamental question: are segments analysed into "parts" that define them, or are they truly atomic — units which are not further divisible or analysable?

1. Scientific Questions About Speech Sounds

One of the scientific questions that can be asked about language is: **what is a possible speech sound?** Humans can produce many more sounds than those systematically used in language. One limitation on language regards modality — lanuage sounds are produced exclusively within the mouth and nasal passages, in the area between the lips and larynx. No language employs hand-clapping, finger-snapping, or vibrations of air between the hand and cheek caused by release of air from the mouth when obstructed by the palm of the hand (though such a sound can communicate an attitude). Even staying within the vocal tract, languages also do not, for example, use whistles or inhalation to form speech sounds, nor is a labio-lingual trill (a.k.a. 'the raspberry') a speech sound in any language. It is important to understand that even though these various odd sounds are not language sounds, they may still be used in communication. The 'raspberry' in American culture communicates a contemptuous attitude; in parts of coastal East Africa and Scandi-

navia, inhaling with the tongue in the position for schwa expresses agreement. Such noises lie outside of language, and we never find plurality indicated with these sounds, nor are they surrounded by other sounds to form the word 'dog'. General communication, for all intents and purposes, has no systematic limitations short of anatomical ones, but in language, only a restricted range of sounds can be employed.

The issue of possible speech sounds is complicated by manual languages such as American Sign Language. ASL is technically not be a counterexample to a claim about modality framed in terms of 'speech sounds'. But it is arbitrary to declare manual language to be outside of the theory of language, and facts from such languages are relevant in principle. Unfortunately, knowledge of the signed languages of the world is very restricted, especially in phonology. Signed languages clearly have syntax: what isn't clear is what they have by way of phonologies. Researchers have only just begun to scratch the surface of sign language phonologies, so unfortunately we can say nothing more about them here.

The central question then must be posed: what is the basis for defining possible speech sounds?

1.1. Possible Differences in Sounds

One way to approach this is to collect samples of the sounds of all of the languages in the world. This search (which has never been conducted) would reveal massive repetition, and would probably reveal that the segment [m] in English is exactly the same as the segment [m] in French, German, Tübatülabal, Arabic, Swahili, Chinese and innumerable other languages. It would also reveal differences, some of them perhaps a bit surprising. Given the richness of our transcriptional resources for notating phonetic differences between segments, one might expect that if a collection of languages had the same vowels transcribed as [i] and [ɩ], then these vowels should sound the same. This is not so.

Varieties of phonetic [i] vs. [ɩ]. Many languages have this pair of vowels; for example, Kimatuumbi has the vowels [i] and [ɩ]. But the actual pronunciation of [i] vs. [ɩ] differs between English and Kimatuumbi. In Kimatuumbi, [i] is higher than in English, and Kimatuumbi [ɩ] is a bit lower than English [ɩ] is — to some people it almost sounds like [e] (but is clearly different from [e], even the 'pure' [e] found in Spanish). This might force us to introduce new symbols, so that we can accurately represent these distinctions.[1] Before we embark on a program of adding new symbols, we should be sure that we know how many symbols we have to add. It turns out that the pronunciation of [i] and [ɩ] differs in many languages: these

[1] This is done in most publications on Kimatuumbi, where the difference is notated as 'extreme' *i̧, u̧* versus 'regular' *i, u*.

vowels exist in English, Kikamba, Elomwe, Kimatuumbi, Bari, Kipsigis, Didinga and Sesotho, and the actual pronunciation of the vowels differs in each language.

You do not have to go very far into exotic languages to find this phonetic difference, for the difference between English [i] and German [i] is also very noticeable, and is something that a language-learner must master to develop a good German or English accent. Although the difference may be difficult for the untrained ear to perceive at first, they are consistent and physically measurable. If written symbols are to represent phonetic differences between languages, a totally accurate transcription should represent these differences. To represent just this range of vowel differences involving [i] and [ɪ], over a dozen new symbols would need to be introduced.

Other variants of sounds. Similar variation exists with other phonetic categories. The retroflex consonants of Telugu, Hindi, and Ekoti are all pronounced differently. Hindi has what one might call 'mild' retroflexion, where the tip of the tongue is placed just behind the alveolar ridge, while in Telugu, the tip of the tongue is further back and contact is made between the palate and the underside of the tongue (sub-laminal); in Ekoti, the tongue is placed further forward, but is also sub-laminal. Finnish, Norwegian, and English contrast the vowels [a] and [æ], but in each of these languages the vowels are pronounced in a slightly different way. The voiced velar fricative [γ] found in Arabic, Spanish and the Kurdish language Hawrami are all phonetically different in subtle but audible ways.

The important details of speech. We will not expand our transcription tools to include as many symbols as needed to capture the myriad of fine distinctions between similar sounds of languages. Fine-tuning transcription is tangential to the goals of phonology, and perfect accuracy is simply not possible. Auditory transcriptions are limited in what they can do, and cannot be used to achieve exact reproduction of a speech event via symbols. If a speaker produces the English word 'putt' [pʌt] 10,000 times, no utterance will be exactly identical to any other utterance. They will be very similar, in ways which might be quantified mathematically, but they would not be exactly the same. Productions of the same word by two speakers of the same language have a greater difference, and supposedly similar utterances in different languages can be much more different. There is no limit to the number of physically different utterances which humans can produce, but there are also only a very small number of discrete transcriptional symbols. The reason for this, as we have emphasised in Chapter 1, is that a transcription approximates speech, and omits properties which are unimportant to phonological systems.

Transcriptions actually record a trained analyst's perception of a sound, and are not derived by physical analysis of speech waveforms. Transcriptions include possible perceptual biases from the person describing the language.

Such details are important to phonetics and its interface with phonology, but must be studied quantitatively using acoustic measurements — formant frequencies or segment durations — or articulatorily by measuring the position of the tongue and lips. For the purposes of phonology, these languages have the same

vowels, [i] vs. [ɩ]. The differences in pronunciation come from detail rules that are part of the phonetic grammars of the languages.

What is important to phonology is not exactly how sounds are pronounced, but what types of sound differences can be contrastive — can form the basis for making differences in meaning. Language can contrast tense [i] and lax [ɩ], but cannot further contrast a hyper-tense high vowel (like that found in Kimatuumbi) which we could write as [i^+] with plain tense [i] as in English, or hyper-lax [$ɩ^-$] as in Kimatuumbi with plain lax [ɩ] as found in English. Within a language, you find at most [i] vs. [ɩ]. Languages can have one series of retroflex consonant, and cannot contrast Hindi-style [ʈ] with a Telegu-style phoneme which we might notate as [$ʈ^+$]. The phonology simply has "retroflex", and it is up to the phonetic component of a language to say exactly how a retroflex consonant is pronounced.

It is important to emphasise that these phonetic details are not too subtle to hear. The difference between various retroflex consonants is quite audible, and the difference between English and German [i] is appreciable. Children learning German can hear and reproduce German [i] accurately. Speakers can also tell when someone mispronounces a German [i] as an English [i], and bilingual German-English speakers can easily switch between the two phonetic vowels.

What phonological theory wants to know is: *what is a possible phoneme?* How might we answer this? We could look at all languages and publish a list. A monumental difficulty with that is that there are nearly 7,000 languages, but useful information on around 10% of these languages. Worse, this could only say what phonemic contrasts exist at the present: it does not answer the really interesting question, what the *possible* phonemes are, which may have existed in a language spoken 1000 years ago, or some future language which will be spoken 1000 years hence. We are not just interested in *observation*, we are interested in *prediction*.

In this connection, consider whether a 'bilabial click' is a possible phoneme. We symbolize it as [⊙] — it is like a kiss, but with the lips flat as for [m], not protruded as for [w]. Virtually all languages have bilabial consonants, and we know of dozens of languages with clicks consonants (Dahalo, Sesotho, Zulu, Xhosa, Khoekhoe), so the question is whether the combination 'bilabial' and 'click' can define a phoneme. Such a sound does exist, but in only two closely related languages, !Xoo and Eastern ǂHoan, members of the Khoisan language family. These languages have under 5,000 speakers combined, and given socio-economic factors where these languages are spoken (Namibia and Botswana), it is likely that the languages will no longer be spoken in 200 years. We are fortunate in this case that we have information of these languages which allows us to say that this *is* a phoneme, but things could have turned out differently. The languages could easily have died out without having been recorded, and then we would wrongly conclude that a bilabial click is not a possible phoneme because it has not been observed. In posing the question of possible phonemes, we must be aware that there can be accidental gaps in the database of observed phonemes.

Predictions versus lists of observations. A list of facts is scientifically uninteresting. A basic goal of science is having knowledge that goes beyond what we have observed, because we believe that the universe obeys general laws. A list might be a helpful in building a theory, but we would not want to stop with a list, because it would give us no explanation why that particular list, as opposed to some other arbitrary list, should constitute the possible phonemes of language. The question 'what is a possible phoneme' should thus be answered by reference to a general theory of what speech sounds are made of, just as a theory of 'possible atoms' is based on a general theory of what makes up atoms and rules for putting those bits together. Science is not simply the accumulation and sorting of facts, but rather is the attempt to discover laws that regulate the universe. Such laws make predictions about things that we have yet to observe.

The Law of Gravity predicts that a rock will fall to earth, which say what it will do and by implication what it will not do: it won't go up or sideways. Physicists have observed that subatomic particles decay into other particles. Particles have electrical charge — positive, negative or neutral — and there is a physical law that the charge of a particle is preserved when it decays (adding up the charges of the decay products). The particle known as a "kaon" (K) can be positive (K^+), negative (K^-) or neutral (K^0); a kaon can decay into other particles known as "pions" (π) which also can be positive (π^+), negative (π^-) or neutral (π^0). Thus a neutral kaon may become a positive pion and a negative pion ($K^0 \rightarrow \pi^+ + \pi^-$) or it may become one positive, one negative and one neutral pion ($K^0 \rightarrow \pi^+ + \pi^- + \pi^0$), because in both cases the positives and negatives cancel out and the sum of charges is neutral (0). The Law of Conservation of Charge allows these patterns of decay, and prohibits a neutral kaon from becoming two positive pions ($K^0 \rightarrow \pi^+ + \pi^+$). Of all of the myriad types of particle decay which have been observed, none of them violate this law, a law which predicts what can happen and what cannot.

Analogously, phonological theory seeks to discover the laws for building phonemes, which predict the possible phonemes of languages. We will see what that theory, after considering a related question which defines phonology.

1.2. Possible Rules

Previous chapters have focused on rules, but we haven't paid much attention to how they should be formulated. English has rules defining allowed clusters of two consonants at the beginning of the word. The first set of consonant sequences in (1) is allowed, whereas the second set of sequences is disallowed.

(1) pr pl br bl tr dr kr kl gr gl
*rp *lp *rb *lb *rt *rd *rk *lk *rg *lg

This restriction is very natural and exists in many languages — however, it is not universal and does not reflect any insurmountable problems of physiology or per-

ception. Russian allows many of these clusters, for example [rtutʸ] ‘mercury’ exemplifies the sequence [rt] which is impossible in English.

We could list the allowed and disallowed sequences of phonemes and leave it at that, but this does not explain why these particular sequences are allowed. Why don’t we find a language which is like English, except that the specific sequence [lb] is allowed and the sequence [bl] is disallowed? An interesting generalization regarding sequencing has emerged after comparing such rules across languages. Some languages (e.g. Hawaiian) do not allow any clusters of consonants and some (Bella Coola, a Salishan language of British Columbia) allow any combination of two consonants, but *no* language allows initial [lb] without also allowing [bl]. This is a more interesting and suggestive observation, since it indicates that there is something about such sequences that is not accidental in English; but it is still just a randomly fact from a list of accumulated facts, if we have no basis for characterising classes of sounds, and view the restrictions as restrictions on letters, as sounds with no structure.

There is a rule in English which requires that all vowels be nasalized when they appear before a nasal consonant, and thus we have a rule something like (2).

(2)
ɛ e ɪ i		ɛ̃ ẽ ĩ ĩ	
a ɔ o ʊ	→	ã ɔ̃ õ ʊ̃	/ ___ m, n, ŋ
u ə æ		ũ ə̃ æ̃	

If rules just replace one arbitrary list of sounds by another list when they stand in front of a third arbitrary list, we have to ask why these particular sets of symbols operate together. Could we replace the symbol [n] with the symbol [č], or the symbol [õ] with the symbol [ö], and still have a rule in some language? It is not likely to be an accident that these particular symbols are found in the rule: a rule similar to this can be found in quite a number of languages, and we would not expect this particular collection of letters to assemble themselves into a rule in many languages, if these were just random collections of letters.

Were phonological rules stated in terms of randomly assembled symbols, there would be no reason to expect (3a) to have a different status from (3b).

(3)
a. {p,t,č,k} → {m,n,ñ,ŋ}/ ___ {m,n,ñ,ŋ}
b. {b,p,d,q} → {d,q,b,p} / ___ {s,x,o,ɪ}

Rule (3a) — nasalization of stops before nasals — is quite common, but (3b) is never found in human language. This is not an accident, but rather reflects the fact that the latter process cannot be characterized in terms of a unified phonetic operation applying to a phonetically defined context. The insight which we have implicitly assumed, and make explicit here, is that rules operate not in terms of specific symbols, but in terms of defineable classes. The basis for defining those classes is a set of phonetic properties.

As a final illustration of this point, rule (4a) is common in the world's languages but (4b) is completely unattested.

(4) a. k,g → č,ǰ / __ i,e
b. p,r → i,b / __ o,n

The first rule refers to phonetically definable classes of segments (velar stops, alveopalatal affricates, front vowels), and the nature of the change is definable in terms of a phonetic difference (velars change place of articulation and become alveopalatals). The second rule cannot be characterised by phonetic properties: the sets {p,r}, {i,b} and {o,n} are not defined by some phonetic property, and the changes of [p] to [i] and [r] to [b] has no coherent phonetic characterisation.

These are not just isolated limitations of knowledge, but rather represent extremely large, systematic classes of rule types. (3b) and (4b) are more than just specific rules accidentally missing from the collection of rules which we have discovered so far, they represent a general class of rule, ones where classes of segments are defined arbitrarily. Consider the constraint on clusters of two consonants in English. In terms of phonetic classes, this reduces to the simple rule that the first consonant must be a stop and the second consonant must be a liquid.[2] The second rule changes vowels into nasalized vowels before nasal consonants. The basis for defining these classes will be considered now.

2. Distinctive feature theory

Just saying that rules are defined in terms of phonetic properties is too broad a claim, since it says nothing about the phonetic properties that are relevant. Consider a hypothetical rule, stated in terms of phonetic properties:

> all vowels change place of articulation so that the original difference in formant frequency between F_1 and F_3 is reduced to 1/2 what it originally was, when the vowel appears before a consonant whose duration ranges from 100 to 135 msc.

What renders this rule implausible (no language has one vaguely resembling it) is that it refers to specific numerical durations, and to the difference in frequency between the first and third formant.

The phonetic properties which are the basis of phonological systems are general and somewhat abstract, such as voicing or rounding, and largely are the categories which we have informally been using already: they are not the same, as we will see. The hypothesis of distinctive feature theory is that there is a small set,

[2] This is not the only rule governing consonant sequences at the beginning of the word in English, so for example the voiceless alveolar fricative [s] can be followed by any non-fricative.

around two dozen, of phonetically-based properties which phonological analysis uses. These properties, the **distinctive features**, not only define the possible phonemes of human languages, but also define phonological rules. The classical statement of features derives from Chomsky & Halle 1968. We will use an adapted set of these features, which takes into consideration refinements. Each feature can have one of two values, plus and minus, so for each speech sound, the segment either *has* the property (is [+F_i]) or *lacks* the property (is [-F_i]). In this section, we follow Chomsky & Halle 1968 and present the generally-accepted articulatory correlates of the features, that is, what aspects of production the feature relates to. There are also acoustic and perceptual correlates of features, pertaining to what the segment sounds like, which are discussed by Jakobson, Fant & Halle 1952 using a somewhat different system of features.[3]

2.1. Phonetic Preliminaries

By way of phonetic background to understanding certain features, two phonetic points need to be clarified. First, some features are characterised in terms of the 'neutral position', which is a configuration that the vocal tract is assumed to have immediately prior to speaking. The neutral position, approximately that of the vowel [ɛ], defines relative movement of the tongue.

Second, you need to know a bit about how the vocal folds vibrate, since some feature definitions relate to the effect on vocal fold vibration (which is important, because it provides nearly all of the sound energy of speech). The vocal folds vibrate when there is enough air pressure below the glottis (the opening between the vocal folds) to force the vocal folds apart. This opening reduces subglottal pressure, which allows the folds to close, which then allows air pressure to rebuild to the critical level where the vocal folds are blown apart again. The critical factor that causes the folds to open is that the pressure below the vocal folds is higher than the pressure above.

Air flows from the lungs at a roughly constant rate. Whether there is enough drop in pressure for air to force the vocal folds open is thus determined by the positioning and tension of the vocal folds (how hard it is to force them apart), and the pressure above the glottis. The pressure above the glottis depends on how effectively pressure buildup can be relieved, and this is determined by the degree of constriction in the vocal tract. In short, the configuration of the vocal folds, and the degree and location of constriction above the glottis almost exclusively determine whether there will be voicing.

If the pressure above and below the glottis are nearly equal, air stops flowing and voicing is blocked. So if the vocal tract is completely obstructed (as

[3] An acoustic description considers just physical sound, but a perceptual description factors in the question of how the ear and brain process sound. The difference between 100 Hz and 125 Hz is acoustically the same as that between 5,100 Hz and 5,125 Hz. The two sets are perceptually very different, the former being perceived as 'more separate' and the latter as virtually indistinguishable.

for the production of a voiceless stop like [k]), air flowing through the glottis rapidly equalizes the pressure below and above the glottis, which stops voicing. On the other hand, if the obstruction in the vocal tract is negligible (as it is for example in the vowel [a]), the pressure differential needed for voicing is easily maintained, since air passing through the glottis is quickly vented from the vocal tract.

A voiced stop such as [g] is possible, even though it involves a total obstruction of the vocal tract analogous to that found in [k], because it takes time for pressure to build up in the oral cavity to the point that voicing ceases. Production of [g] involves ancilliary actions to maintain voicing. For example, the pharynx may be widened, which gives the air more room to escape, delaying the buildup of pressure. The larynx may be lowered, which also increases the volume of the oral cavity; the closure for the stop may be weakened slightly, allowing tiny amounts of air to flow through; the velum may be raised somewhat to increase the size of the air cavity, or it may be lowered somewhat to allow small (usually imperceptible) amounts of air to pass through the nose. The duration of the consonant can be reduced — generally, voiced stops are phonetically shorter than corresponding voiceless stops are.

Certain sounds such as vowels lack a radical constriction in the vocal tract, so it is quite easy to maintain voicing during such sounds, whereas with other sounds, specifically obstruents, voicing is difficult to maintain. Some accounts of this distinction, especially that of Chomsky & Halle 1968, refer to 'spontaneous voicing', which is grounded on the assumption that voicing occurs automatically simply by positioning the vocal folds in what we might call the 'default' position. For sounds that involve a significant obstruction of the vocal tract, special actions are required for voicing. The features [sonorant] and [consonantal] directly relate to the obstruction in the vocal tract, which determines whether the vocal folds vibrate spontaneously.

2.2. Major Class Features

One of the most intuitive distinctions which feature theory needs to capture is that between consonants and vowels. There are three features, the so-called major class features, which provide a rough first grouping of sounds into functional types that includes the consonant/vowel distinction.

syllabic: forms a syllable peak (and thus can be stressed).
sonorant: sounds produced with a vocal tract configuration in which spontaneous voicing is possible.
consonantal: sounds produced with a major obstruction in the oral cavity.

The feature [syllabic] is, unfortunately, simultaneously one of the most important features and one of the hardest to define physically. It corresponds intuitively to the notion 'consonant' (where [h], [y], [m], [s] [t] are 'consonants') ver-

sus ‘vowel’ (such as [a], [i]): indeed the only difference between the vowels [i,u] and the corresponding glides [y,w] is that [i,u] are [+syllabic] and [y,w] are [-syllabic]. The feature [syllabic] goes beyond the intuitive vowel/consonant split. English has phonetic syllabic sonorants, such as [r̩], [l̩], [n̩]. The main distinction between the English words (American English pronunciation) “ear” [ɪr] and “your” [yr̩] resides in which segments are [+syllabic] versus [-syllabic]. In “ear”, the vowel [ɪ] is [+syllabic] and [r] is [-syllabic], whereas in “your”, [y] is [-syllabic] and [r̩] is [+syllabic]. The words “eel” [il] and the reduced form of “you’ll” [yl̩] for many speakers of American English similarly differ in that [i] is the peak of the syllable (is [+syllabic]) in “eel”, but [l̩] is the syllable peak in “you’ll”.

Other languages have syllabic sonorants which phonemically contrast with nonsyllabic sonorants, such as Serbo-Croatian which contrasts syllabic [r̩] with nonsyllabic [r] (cf. *groze* ‘fear (gen.)’ versus *gr̩oce* ‘little throat’). Swahili distinguishes [mbuni] “ostrich” and [m̩buni] “coffee plant” in the fact that [m̩buni] is a three-syllable word and [m̩] is the peak (the only segment) of that first syllable, but [mbuni] is a two syllable word, whose first peak is [u]. Although such segments may be thought of as ‘consonants’ in one intuitive sense of the concept, they have the feature value [+syllabic]. This is a reminder that there is a difference between popular concepts about language and technical terms. ‘Consonant’ is not strictly speaking a technical concept of phonological theory, even though it is quite frequently used by phonologists — almost always with the meaning ‘non-peak’ in the syllable, i.e. a [-syllabic] segment.

The feature [sonorant] captures the distinction between segments such as vowels and liquids where the constriction in the vocal tract is small enough that no special effort is required to maintain voicing, as opposed to sounds such as stops and fricatives which have enough constriction that effort is needed to maintain voicing. In an oral stop, air cannot flow through the vocal tract at all, so oral stops are [-sonorant]. In a fricative, even though there is some airflow, there is so much constriction that pressure builds up, so that spontaneous voicing is not possible, thus fricatives are [-sonorant]. In a vowel or glide, the vocal tract is only minimally constricted so air can flow without impedance: vowels and glides are therefore [+sonorant]. A nasal consonant like [n] has a complete obstruction of airflow through the oral cavity, but nevertheless the nasal passages are open which allows free flow of air. Air pressure does not build up during the production of nasals, so nasals are [+sonorant]. In the liquid [l], there is a complete obstruction formed by the tip of the tongue with the alveolar ridge, but nevertheless air flows freely over the sides of the tongue so [l] is [+sonorant].

The question whether *r* is [+sonorant] or [-sonorant] has no simple answer, since many phonetically different segments are transcribed as *r*; some are [-sonorant] and some are [+sonorant], depending on their phonetic properties. The so-called fricative *r* of Czech (spelled *ř*) has a considerable constriction, so it is [-sonorant], but the English-type [r] is a sonorant since there is very little constric-

tion. In other languages there may be more of a constriction, but the constriction is so brief that it does not allow significant buildup of air pressure (this would be the case with 'tapped' *r*'s). Even though spontaneous voicing is impossible for the laryngeal consonants [h,ʔ] because they are formed by positioning the vocal folds so that voicing is precluded, they are [+sonorant] since they have no constriction above the glottis.[4]

The feature [consonantal] is very similar to the feature [sonorant], but specifically addresses the question of whether there is any major constriction in the oral cavity. This feature groups together obstruents, liquids and nasals which are [+consonantal], versus vowels, glides and laryngeals ([h,ʔ]) which are [-consonantal]. Vowels and glides have a minor obstruction in the vocal tract, compared to that formed by a fricative or a stop. Glottal stop is formed with an obstruction at the glottis, but none in the vocal tract, hence it is [-consonantal]. In nasals and liquids, there is an obstruction in the oral cavity, even though the overall constriction of the whole vocal tract is not high enough to prevent spontaneous voicing. Recent research indicates that this feature may not be necessary, since its function is usually covered as well or better by other features.

The most important phonological use of features is that they identify classes of segments in rules. All speech sounds can be analysed in terms of their values for the set of distinctive features, and the set of segments that have a particular value for some feature (or set of feature values) is a **natural class**. Thus the segments [a i r̩ m̩] are members of the [+syllabic] class, and [y h ʔ r m s p] are members of the [-syllabic] class; [a r̩ y ʔ r m] are in the [+sonorant] class and [s z p b] are in the [-sonorant] class; [a i w h ʔ] are in the [-consonantal] class and [r̩ m̩ r m s p] are in the [+consonantal] class. Natural classes can be defined in terms of conjunctions of features, such as [+consonantal, -syllabic] which refers to the set of segments which are simultaneously [+consonantal] and [-syllabic]. Accordingly, the three major class features combine to define six classes, exemplified by the following segment groups.

(5)

	a,i,u	r̩,l̩,m̩	y,w	h,ʔ	r,l,m	s,z,p,b
syllabic	+	+	-	-	-	-
sonorant	+	+	+	+	+	-
consonantal	-	+	-	-	+	+

One thing to note is that all [+syllabic] segments, i.e. all syllable peaks, are also [+sonorant]. It is unclear whether there are syllabic obstruents, i.e. [s̩], [k̩]. It has been claimed that such things exist in certain dialects of Berber, but their interpretation remains controversial, since the principles for detection of syllables are con-

[4] The definitions of [sonorant] could be changed so that glottal configuration is also included, so that the laryngeals would be [-sonorant]. There is little compelling evidence to show whether this would be correct; later, we discuss how to go about finding such evidence for revising feature definitions.

troversial. Another gap is the combination [-sonorant, -consonantal], which would be a physical impossibility. A [-sonorant] segment would require a major obstruction in the vocal tract, but the specification [-consonantal] entails that the obstruction could not be in the oral cavity. The only other possibility would be constriction of the nasal passages, and nostrils are not sufficiently constrictable.

2.3. Place of Articulation

Features to define place of articulation are our next functional set. We begin with the features typically used by vowels, specifically the [+syllabic, -consonantal,+sonorant] segments, and then procede to consonant features, ending with a discussion of the intersection of these features.

Vowel place features. The features which define place of articulation for vowels are the following.

high: the body of the tongue is raised from the neutral position.
low: the body of the tongue is lowered from the neutral position.
back: the body of the tongue is retracted from the neutral position.
round: the lips are protruded.
tense: sounds requiring deliberate, accurate, maximally distinct gestures that involves considerable muscular effort.
advanced tongue root: produced by drawing the root of the tongue forward.

The main features are [high], [low], [back] and [round]. Phonologists primarily distinguish just front and back vowels, governed by [back]: front vowels are [-back] since they do not involve retraction of the tongue body, and back vowels are [+back]. Phonetic central vowels are usually treated as phonological back vowels, since typically central vowels are unrounded and back vowels are rounded. Distinctions such as between the mid vowels [ɵ], [ə], [ɤ], [ɜ] and [ʌ], or the high vowels [ɨ], [ʉ] and [ɯ], are considered to be phonologically unimportant over-differentiations of language-specific phonetic values of phonologically back unrounded vowels. In lieu of clear examples of a contrast between central and back rounded vowels, or central and back unrounded vowels, we will not at the moment postulate any feature for the front-back dimension, though section 6 considers evidence for the phonological relevance of the concept ‘central vowel’.

Two main features are employed to represent vowel height. High vowels are [+high] and [-low], low vowels are [+low] and [-high]. No vowel can be simultaneously [+high] and [+low] since the tongue cannot be raised and lowered simultaneously; mid vowels are [-high,-low]. In addition, any vowel can be produced with lip rounding, using the feature [round]. These features allow us to characterize the following vowel contrasts.

(6)

	i	ü	ɨ	u	e	ö	ʌ	o	æ	œ	ɑ	ɒ
high	+	+	+	+	-	-	-	-	-	-	-	-
low	-	-	-	-	-	-	-	-	+	+	+	+
back	-	-	+	+	-	-	+	+	-	-	+	+
round	-	+	-	+	-	+	-	+	-	+	-	+

Note that [ɑ] is a back low unrounded vowel, in contrast to the symbol [ɒ] for a back low rounded vowel. As noted in chapter 2, IPA uses more vowel symbols that are typical for reporting linguistic data, especially among low vowels which includes [æ a ɐ ɑ ɒ]. Phonological sources typically use <a> to indicate a low non-round, non-front vowel — IPA [ɑ] — and do not distinguish <a>, <ɑ> or <ɐ>.

Vowels with a laxer, 'less deliberate' and lower articulation, such as [ɪ] in English 'sit' or [ɛ] in English 'set' would be specified as [-tense].

(7)

	ɪ	ʊ̈	ɨ	ʊ	ɛ	ɔ̈	ə	ɔ
high	+	+	+	+	-	-	-	-
low	-	-	-	-	-	-	-	-
back	-	-	+	+	-	-	+	+
round	-	+	-	+	-	+	-	+
tense	-	-	-	-	-	-	-	-

One question which has not been resolved is the status of low vowels in terms of this feature. Unlike high and mid vowels, there do not seem to be analogous contrasts between low vowels between tense vs. lax [æ]. Another important point about this feature is that while [back], [round], [high] and [low] will also play a role in defining consonants, [tense] plays no role in consonantal contrasts.

The difference between *i* and *ɪ*, or *e* and *ɛ* has also been considered to be one of vowel height (proposed in alternative models where vowel height is governed by a single scalar vowel height feature, rather than by the binary features [high] and [low]). This vowel contrast has also been described in terms of the features 'Advanced Tongue Root' (ATR), especially in the vowel systems of languages of Africa and Siberia. There has been debate over the phonetic difference between [ATR] and [tense]. Typically, [+tense] front vowels are fronter than their lax counterparts, and [+tense] back vowels are backer than their lax counterparts. In comparison, [+ATR] vowels are supposed to be generally fronter than corresponding [-ATR] vowels are, so that [+ATR] back vowels are phonetically fronter than their [-ATR] counterparts. However, some articulatory studies have shown that the physical basis for the tense/lax distinction in English is no different from that which ATR is based on. Unfortunately, the clearest examples of the feature [ATR] are found in languages of Africa, where very little phonetic research has been done. Since no language contrasts both [ATR] and [tense] vowels, it is usu-

ally supposed that there is a single feature, whose precise phonetic realization varies somewhat from language to language.

Consonant place features. The main features used for defining consonantal place of articulation are the following.

coronal: produced with the blade or tip of the tongue raised from the neutral position.
anterior: produced with an obstruction located at or in front of the alveolar ridge.
strident: produced with greater noisiness.
distributed: produced with a constriction that extends for a considerable distance along the direction of air flow.

Place of articulation in consonants is primarily described with the features [coronal] and [anterior]. Labials, labiodentals, dentals and alveolars are [+anterior] since their primary constriction is in front of the alveolar ridge (either with the lips, the teeth, or just back of the teeth) whereas other consonants (including laryngeals) are [-anterior], since they lack this forward constriction. The best way to understand this feature is to remember that it is the defining difference between [s] and [š], where [s] is [+anterior] and [š] is [-anterior]. Anything produced where [s] is produced, or in front of that position, is therefore [+anterior]; anything produced where [š] is, or behind [š] is [-anterior].

(8)	[+anterior]	[-anterior]
	f φ p θ s t̪ t	š č ṣ ṭ ç x k q ʕ h ʔ

Consonants which involve the blade or tip of the tongue are [+coronal], and this covers the dentals, alveolars, alveopalatals and retroflex consonants. Consonants at other places of articulation — labial, velar, uvular and laryngeal — are [-coronal]. Note that this feature does not encompass the body (back) of the tongue, so while velars and uvulars use the tongue, they use the body of the tongue rather than the blade or tip, and therefore are [-coronal]. The division of consonants into classes as defined by [coronal] is illustrated below.

(9)	[+coronal]	[-coronal]
	t̪ θ t s š n l r ñ ṭ	p φ f k q ʕ

Two other features are important in characterizing the traditional places of articulation. The feature [distributed] is used in coronal sounds to distinguish dental [t̪] from alveolar [t], or alveopalatal [š] from retroflex [ṣ]: the segments [t̪,š] are [+distributed] and [t,ṣ] are [-distributed]. The feature [distributed], as applied to coronal consonants, corresponds to the traditional phonetic notion 'apical'

([-distributed]) versus 'laminal' ([+distributed]): this feature is not relevant for velar and labial sounds and we will not specify any value of [distributed] for non-coronal segments.

The feature [strident] distinguishes strident [f,s] from nonstrident [φ,θ]: otherwise, the consonants [f,φ] would have the same feature specifications. Note that the feature strident is defined in terms of the aerodynamic property of greater turbulence (which has the acoustic correlate of greater noise), not in terms of the movement of a particular articulator — this defining characteristic is accomplished by different articulatory configurations. In terms of contrastive usage, the feature [strident] only serves to distinguish bilabial and labiodentals, or interdentals and alveolars. A sound is [+strident] only if it has greater noisiness, and 'greater' implies a comparison. In the case of [φ] versus [f], [β] versus [v], [θ] versus [s], or [ð] versus [z] the second sound in the pair is noisier. No specific degree of absolute noisiness has been proposed which would allow one to determine in isolation whether a given sound meets the definition of strident or not. Thus it is impossible to determine whether [š] is [+strident], since there is no contrast between strident and non-strident alveopalatal sounds. The phoneme [š] is certainly relatively noisy — noisier than [θ] is — but then [θ] is noisier than [φ] is.

[Strident] is not strictly necessary for making a distinction between [s] and [θ], since [distributed] also distinguishes these phonemes. Since [strident] is therefore only crucial for distinguishing bilabial and labial fricatives, it seems questionable to postulate a feature with such broad implications solely to account for the contrast between labiodental and bilabial fricatives. Nonetheless, we need a way of representing this contrast. The main problem is that there are very few languages (such as Ewe, Venda and Shona) which have both [f] and [φ], or [v] and [β], and the phonological rules of these languages do not give us evidence as to how this distinction should be made in terms of features. We will therefore only invoke the feature [strident] in connection with the [φ,β] vs. [f,v] contrast.

Using these three features, consonantal places of articulation can be partially distinguished as follows.

(10)		p	t̪	t	č	ṭ	k,q,ʕ,ʔ
	anterior	+	+	+	-	-	-
	coronal	-	+	+	+	+	-
	distributed		+	-	+	-	

Vowel features on consonants. The features [high], [low], [back] and [round] are not reserved exclusively for vowels, and these typical vowel features can play a role in defining consonants as well. As we see in (10), velar, uvular, pharyngeal and glottal places of articulation are not yet distinguished; this is where the features [high], [low] and [back] become important. Velar, uvular and pharyngeal consonants are [+back] since they are produced with a retracted tongue body. The difference between velar and uvular consonants is that with velar consonants the

tongue body is raised, whereas with uvular consonants it is not, and thus velars are [+high] where uvulars are [-high]. Pharyngeal consonants are distinguished from uvulars in that pharyngeals are [+low] and uvulars are [-low], indicating that the constriction for pharyngeals is even lower than that for uvulars.

One other traditional phonetic place of articulation for consonants is that of 'palatal' consonants. The term 'palatal' is used in many ways, for example the post-alveolar or alveo-palatal (palato-alveolar) consonants [š] and [č] might be refered to as palatals. This is strictly speaking a misnomer, and the term 'palatal' is best used only for the 'true palatals', transcribed in IPA as [c ç ɟ]. Such consonants are found in Hungarian, and also in German in words like [iç] 'I' or in Norwegian [çö:per] 'buys'. These consonants are produced with the body of the tongue raised and fronted, and therefore they would have the feature values [+hi,-back]. The classical feature system presented here provides no way to distinguish such palatals from palatalized velars ([k^y]) either phonetically or phonologically. Palatalized (fronted) velars exist as allophonic variants of velars before front vowels in English e.g. [k^yip] 'keep'; they are articulatorily and acoustically extremely similar to the palatals of Hungarian. Very little phonological evidence is available regarding the treatment of 'palatals' versus 'palatalized velars': it is quite possible that [c] and [k^y], or [ç] and [x^y], are simply different symbols, chosen on the basis of phonological patterning rather than systematic phonetic differences.

With the addition of these features, the traditional places of articulation for consonants can now be fully distinguished.

(11)

	p	t̪	t	č	ṭ	c,k^y	k	q	ʕ	ʔ
anterior	+	+	+	-	-	-	-	-	-	-
coronal	-	+	+	+	+	-	-	-	-	-
distributed		+	-	+	-					
hi	-	-	-	-	-	+	+	-	-	-
back	-	-	-	-	-	-	+	+	+	-
low	-	-	-	-	-	-	-	-	+	-

The typical vowel features have an additional function as applied to consonants, namely that they define secondary articulations such as palatalization and rounding. Palatalization involves superimposing the raised and fronted tongue position of the vowel [i] or the glide [y] onto the canonical articulation of a consonant, thus the features [+high,-back] are added to the primary features that characterise a consonant (those being the features that typify [i,y]). So, for example, the essential feature characteristics of a bilabial are [+anterior,-coronal] and they are only incidentally [-hi,-back]. A palatalized bilabial would thus be [+anterior,-coronal,+hi,-back]. Velarized consonants would then have the features [+high,+back] analogous to the features of velar consonants; pharyngealized consonants would have the features [+back,+low]. Consonants may also bear the fea-

ture [round]. Applying various possible secondary articulations to labial consonants results in the following specifications.

(12)

	p	p^{y}	p^{γ},$p^{ɯ}$	p^{w}	$p^{ẅ}$	$p^{ʕ}$	p^{q}	p^{o}	$p^{ö}$
hi	-	+	+	+	+	-	-	-	-
back	-	-	+	+	-	+	+	+	-
low	-	-	-	-	-	+	-	-	-
round	-	-	-	+	+	-	-	+	+

Labialised (p^{w}), palatalised (p^{y}), velarised (p^{γ},$p^{ɯ}$) and pharyngealised ($p^{ʕ}$) variants are the most common categories of secondary articulation. Uvularised consonant, i.e. p^{q}, are rare: uvularized clicks are attested in Ju /'hoansi. It is unknown if there is a contrast between rounded consonants differing in secondary height, symbolised above as p^{w} vs. p^{o} or $p^{ẅ}$ vs. $p^{ö}$. Feature theory allows such a contrast, so eventually we ought to find examples. If, as seems likely after some decades of research, such contrasts do not exist where predicted, there should be a revision of the theory, so that the predictions of the theory better match observations.

This treatment of secondary articulations makes other predictions. One is that there cannot be palatalized uvulars or pharyngeals. This follows from the fact that the features for palatalization ([+high,-back]) conflict with the features for uvulars ([-hi,+back]) and pharyngeals ([-hi,+back,+low]). Since such segments do not appear to exist, this supports the theory: otherwise we expect — in lieu of a principle that prohibits them — that they will be found in some language. Second, in this theory a 'pure' palatal consonant (such as Hungarian [ɟ]) is equivalent to a palatalized (i.e. fronted) velar. Again, since no language makes a contrast between a palatal and a palatalised velar, this is a good prediction of the theory (unless such a contrast is uncovered, in which case it becomes a bad prediction of the theory).

2.4. Manner of Articulation

Other features relate to the manner in which a segment is produced, apart from the location of the segment's constriction. The manner features are:

continuant: the primary constriction is not narrowed so much that air flow through the oral cavity is blocked.
delayed release: release of a total constriction is slowed so that a fricative is formed after the stop portion.
nasal: the velum is lowered which allows air to escape through the nose.
lateral: the mid section of the tongue is lowered at the side.

The feature [continuant] groups together vowels, glides, fricatives and [h] as [+continuant]. Note that [continuant] is a broader group than the traditional no-

tion ‘fricative’ which refers to segments such as [s], [š] or [θ]. The term ‘fricative’ generally refer to non-sonorant continuants, i.e. the class defined by the conjunction of features [+continuant,-sonorant]. Since continuants are defines as sounds where air can flow continuously through the oral cavity, nasals like [m n ŋ] are [-continuant], even though they allow continuous air flow (through the nose).

Affricates such as [č, p^f] are characterised with the feature [+delayed release]. Necessarily, all affricates are [-continuant], since they involve complete constriction followed by a period of partial fricative-like constriction, and therefore they behave essentially as a kind of stop. This feature is in question, since [p^f č k^x] do not act as a unified phonological class; nevertheless, some feature is needed to characterise stops versus affricates. Various alternatives have been proposed, for example that [k^x] might just be the pronunciation of aspirated [k^h] since velar [k^x] and [k^h] never contrast; perhaps the feature [strident] defines [t^s] vs. [t]. The proper representation of affricates is a currently unsolved issue in phonology.

The feature [+nasal] is assigned to sounds where air flows through the nasal passages, for example [n] as well as nasalised vowels like [ã]. Liquids and fricatives can be nasalised as well, but the latter especially are quite rare. L-like sounds are characterised with the feature [lateral]. Almost all [lateral] sounds are coronal, though there are a few reports of velar laterals: detailed information on the phonetics and phonology of these segments is not available.

Examples of the major manners of articulation are illustrated below, for coronal place of articulation.

(13)

	t	n	t^s	s	l	$t^l = \lambda$
delayed release	-	-	+	-	-	+
continuant	-	-	-	+	+	-
lateral	-	-	-	-	+	+

2.5. Laryngeal Features

Three features characterise the state of the glottis.

spread glottis: the vocal folds are spread far apart.
constricted glottis: the vocal folds are tightly constricted.
voice: the vocal folds vibrate.

Voiced sounds are [+voice]. The feature [spread glottis] describes aspirated obstruents ([p^h], [b^h]) and breathy sonorants ([m̤], [a̤]); [constricted glottis] describes implosive ([ɓ]) and ejective obstruents ([p’]), and laryngealized sonorants ([m̰], [a̰]).

How to distinguish implosives from ejectives is not entirely obvious, but the standard answer is that ejectives are [-voice] and implosives are [+voice].

There are two problems with this. One is that implosives do not generally pattern with other [+voiced] consonants in phonological systems, especially in how consonants affect tone (voiced consonants, but typically not implosives, may lower following tones). The second is that Ngiti and Lendu have both voiced and voiceless implosives. The languages lack ejectives, which raises the possibility that voiceless implosives are phonologically [-voice,+c.g], which is exactly the specification given to ejective consonants. You may wonder how [-voice,+c.g.] can be realised as an ejective in languages like Navajo, Tigre or Lushootseed, and as a voiceless implosive in Ngiti or Lendu. This is possible because feature values give approximate phonetic descriptions, not exact ones. The Korean 'fortis' consonants, found in [k'ata] "peel (noun)", [ak'i] "musical instrument" or [alt'a] "be ill" are often described as glottalised, and phonetic studies have shown that they are produced with glottal constrictions: thus they would be described as [-voice,+c.g]. Nevertheless, they are not ejectives. Similarly, Khoehoe (Nama) has a contrast between plain clicks ([!àḿ] 'deep') and glottalised ones ([!'áḿ] 'kill'), but the glottalised clicks realise the feature [+c.g.] as a simple constriction of the glottis, not involving an ejective release.

The usual explanation for the difference between ejectives in Navajo and glottalised non-ejective consonants in Korean or Khoekhoe is that they have the same phonological specifications, [-voice,+c.g.], but realise the features differently due to language specific differences in principles of phonetic implementation. This is an area of feature theory where more research is required.

The representations of laryngeal contrasts in consonants are given below.

(14)

	p	b	ɓ	p'	p^h	$b^ɦ$
voice	-	+	+	-	-	+
c.g.	-	-	+	+	-	-
s.g.	-	-	-	-	+	+

2.6. Prosodic Features

Finally, in order to account for the existence of length distinctions, and to represent stressed versus unstressed vowels, two other features were proposed.

long: has greater duration.
stress: has greater emphasis, higher amplitude and pitch, longer duration.

These are obvious: long segments are [+long] and stressed vowels are [+stress].

A major lacuna in the Chomsky & Halle 1968 account of features is a lack of features for tone. This is remedied in Chapter 11 when we introduce nonlinear representations. For the moment, we can at least assume that tones are governed by

a binary feature [±High-tone] — this allows only two levels of tone, but we will not concentrate heavily on languages with more than two tone levels.

2.7. Summary of Feature Values

Features combine quite freely, so we cannot give a complete list. By learning some specific feature values and applying your knowledge of the meaning of features, it should be possible to arrive at the feature values of other segments. This is, of course, possible only if you know relevant phonetic details of the sound that you are considering. In order to know the feature values of [ɭ], you need to know that this is the symbol for a retroflex lateral approximant, thus it has the features appropriate for [l], and it also has the features that characterize retroflex consonants, which are [-ant,-dist]. If you do not know the phonetic characteristics of the segment symbolized as [ʕ], it is necessary to first understand its phonetic properties — it is a voiced pharyngeal continuant — before trying to deduce its feature values. In reading descriptions of languages, it is also important to understand that a symbol used in published data on a language is not always used according to a particular standard of phonetic transcription practices at the moment, so read the phonetic descriptions of letters in the grammar carefully!

The standard feature values for the consonants of (American) English are given in (15), to help you understand how the entire set of features is applied to the sound inventory of a language which you are familiar with.

(15)

	p	t	č	k	b	d	ǰ	g	f	v	θ	ð
syl.	-	-	-	-	-	-	-	-	-	-	-	-
son.	-	-	-	-	-	-	-	-	-	-	-	-
cons.	+	+	+	+	+	+	+	+	+	+	+	+
cont.	-	-	-	-	-	-	-	-	+	+	+	+
del.rel.	-	-	+	-	-	-	+	-	-	-	-	-
lat.	-	-	-	-	-	-	-	-	-	-	-	-
nas	-	-	-	-	-	-	-	-	-	-	-	-
voi.	-	-	-	-	+	+	+	+	-	+	-	+
c.g.	-	-	-	-	-	-	-	-	-	-	-	-
s.g.	(-	-	-	-)	-	-	-	-	-	-	-	-
ant.	+	+	-	-	+	+	-	-	+	+	+	+
cor.	-	+	+	-	-	+	+	-	-	-	+	+
dist.		-	+			-	+				+	+
hi	-	-	-	+	-	-	-	+	-	-	-	-
lo	-	-	-	-	-	-	-	-	-	-	-	-
back	-	-	-	+	-	-	-	+	-	-	-	-
round	-	-	-	-	-	-	-	-	-	-	-	-

	s	z	š	ž	h	ʔ	m	n	ŋ	r	l	y	w
syl.	-	-	-	-	-	-	-	-	-	-	-	-	-
son.	-	-	-	-	+	+	+	+	+	+	+	+	+
cons.	+	+	+	+	-	-	+	+	+	-	+	-	-
cont.	+	+	+	+	+	-	-	-	-	+	+	+	+
del.rel.	-	-	-	-	-	-	-	-	-	-	-	-	-
lat.	-	-	-	-	-	-	-	-	-	-	+	-	-
nas	-	-	-	-	-	-	+	+	+	-	-	-	-
voi.	-	+	-	+	-	-	+	+	+	+	+	+	+
c.g.	-	-	-	-	-	+	-	-	-	-	-	-	-
s.g.	-	-	-	-	+	-	-	-	-	-	-	-	-
ant.	+	+	-	-	-	-	+	+	-	-	+	-	-
cor.	+	+	+	+	-	-	-	+	-	+	+	-	-
dist.	-	-	+	+				-		-	-		
hi	-	-	-	-	-	-	-	-	+	+	-	+	+
lo	-	-	-	-	-	-	-	-	-	-	-	-	-
back	-	-	-	-	-	-	-	-	+	+	-	-	+
round	-	-	-	-	-	-	-	-	-	-	-	-	+

The type of *r* we have in English is unusual and could better be transcribed as [ɹ^{w}] — in fact, pronunciation of "r" differs between English dialects. Do not assume that the features of "r" in some other language such as Finnish, Spanish or Chinese are the same as those for English.

The assignment of [spread glottis] — aspiration — in English stops varies according to context, so the value [-s.g.] is in parenthesis in the chart because both values of this feature are found on the surface, depending on context. The value [-s.g.] represents the underlying value.

Vowel feature summary. Certain feature values are uniform for all vowels: [+syl, -cons, +son, +cont, -del.rel., -cor, -ant, -lat, -dist.]. Typically, vowels are also [+voice,-s.g,-c.g.]. There are languages such as Mazateco and !Xoo where breathy voicing and glottalization are used contrastively, so in these languages [+s.g.] and [+c.g.] are possible specifications. A number of languages have phonetic voiceless vowels, but the phonological status of voiceless vowels is not so clear, thus it may be that there are no phonologically [-voice] vowels. Values of the main features used to distinguish vowels are given in (16).[5]

(16)

	i	ü	ɨ	u	e	ö	ʌ	o	æ	œ	ɑ	ɒ
high	+	+	+	+	-	-	-	-	-	-	-	-
low	-	-	-	-	-	-	-	-	+	+	+	+
back	-	-	+	+	-	-	+	+	-	-	+	+
round	-	+	-	+	-	+	-	+	-	+	-	+
tense	+	+	+	+	+	+	+	+				

[5] Recall that we are not certain whether [tense] applies to low vowels.

	ɪ	ʊ̈	ɨ	ʊ	ɛ	ɔ̈	ə	ɔ
high	+	+	+	+	-	-	-	-
low	-	-	-	-	-	-	-	-
back	-	-	+	+	-	-	+	+
round	-	+	-	+	-	+	-	+
tense	-	-	-	-	-	-	-	-

Nasality, length, breathiness and creaky voice are properties freely available to vowels, so any of these vowels can have ±nasal, ±long, ±s.g. or ±c.g. counterparts.

Consonant feature summary. Primary place of articulation for consonants is summarised in (17), using continuant consonants (voiceless in the first row, voiced in the second: numbers in the third row are keyed to traditional place of articulation terms). Continuant consonants are used here because they exhibit the maximum number of distinctions, for example there are bilabial and labiodental fricatives, but only bilabial stops. All of these consonants are [-syl, -son, +cons, +cont, -del.rel., -nas, -lat, -s.g., -c.g., -tense, -rnd].

(17)

1:	bilabial	2:	labiodental
3:	(inter-)dental	4:	alveolar
5:	alveopalatal/postalveolar	6:	retroflex
7:	palatal	8:	velar
9:	uvular	10:	pharyngeal
11:	glottal/laryngeal		

	φ	f	θ	s	š	ʂ	ç	x	χ	ħ	h
	β	v	ð	z	ž	ʐ	ʝ	γ	ʁ	ʕ	ɦ
	1	2	3	4	5	6	7	8	9	10	11
ant.	+	+	+	+	-	-	-	-	-	-	-
cor.	-	-	+	+	+	+	-	-	-	-	-
dist.			+	-	+	-					
hi	-	-	-	-	-	-	+	+	-	-	-
lo	-	-	-	-	-	-	-	-	-	+	-
back	-	-	-	-	-	-	-	+	+	+	-

Secondary place of articulation is illustrated in (18), here restricted to secondary articulations on [p t]. All of these consonants are [-syl, -son, +cons, -cont, -del.rel., -lat, -nas, -voice, -s.g., -c.g., -tense].

(18)

	p	p^{w}	$p^{ɯ}$	p^{y}	$p^{ˤ}$	$p^{ɞ}$,$p^{ɥ}$	t	t^{w}	$t^{ɯ}$	t^{y}	$t^{ˤ}$	$t^{ɞ}$,$t^{ɥ}$
ant.	+	+	+	+	+	+	+	+	+	+	+	+
cor.	-	-	-	-	-	-	+	+	+	+	+	+
dist.	-	-	-	-	-	-	-	-	-	-	-	-
hi	-	(+)	+	+	-	+	-	(+)	+	+	-	+
lo	-	-	-	-	+	-	-	-	-	-	+	-
back	-	+	+	-	+	-	-	+	+	-	+	-
round	-	+	-	-	-	+	-	+	-	-	-	+

Round consonants might simply have the specification [+round]. Tongue raising and backing is not necessary in order to achieve rounding, whereas tongue raising and backing is by definition necessary in order to have a velarised consonant.

A final important point must be made. The 20 features discussed here — syllabic, sonorant, consonantal, high, low, back, round, tense (advanced tongue root), coronal, anterior, strident, distributed, continuant, delayed release, nasal, lateral, spread glottis, constricted glottis, voice, long, stress — are specific empirical hypotheses. That means that they are subject to change in the face of evidence that a change is required, so they are not immutable. On the other hand, as scientific hypotheses, they must be taken seriously until good evidence is presented that another system of features are better (see section 6 of this chapter and Chapter 11 for discussion of such changes). Features should not be invented willy-nilly: using distinctive features is not the same as placing a plus sign in front of a traditional articulatory description, and thus describing sounds as [+mid], [+alveolar] or [+vowel] misconstrues the theoretical claim of distinctive features.

3. Features and Classes of Segments

Besides defining phonemes, features play a role in formalizing rules, since rules are stated in terms of features. Every specification, such as [+nasal] or [-voice], defines a class of segments. The generality of a class is inversely related to how many features are required to specify the class, as illustrated in (19).

(19)

[+syllabic]	$\begin{bmatrix} \text{+ syl} \\ \text{- nasal} \end{bmatrix}$	$\begin{bmatrix} \text{+ syl} \\ \text{+ round} \end{bmatrix}$	$\begin{bmatrix} \text{+ syl} \\ \text{+ high} \\ \text{- nasal} \end{bmatrix}$	$\begin{bmatrix} \text{+ syll} \\ \text{- hi} \\ \text{- low} \\ \text{- nas} \\ \text{- tense} \end{bmatrix}$
ɛ e ɪ i ɛ̃ ẽ ĩ ĭ	ɛ e ɪ i	ɔ o ʊ ɔ̃	ɪ i	ə ɛ ɔ
a ɔ o ʊ ã ɔ̃ õ ʊ̃	a ɔ o ʊ	õ ʊ̃ u ũ	ʊ u	
u ə æ ũ ə̃ æ̃		u ə æ		

The most general class, defined by a single feature, is [+syllabic] which refers to all vowels. The size of that class is determined by the segments in the language: [+syllabic] in Spanish refers to [i e a o u], but in English refers to [i ɪ e ɛ æ a ɔ o ʊ u ə ʌ r̩]. As you add features to a description, you narrow down the class, making the class less general. The usual principle adopted in phonology is that simpler rules, which use fewer features, are preferable to rules using more features.

One challenge in formalising rules with features is recognising the features which characterise classes. Discovering the features defining a class boils down to seeing which values are the same for all segments in the set, then checking that no other segment in the inventory also has that combination of values. The main obstacle is that you have to think of segments in terms of their feature properties, which takes practice to become second nature. As an exercise towards understanding the relation between classes of segments and feature descriptions, we will assume a language with the following segments:

(20) p t k b d g f s x v γ w y l m n a e i o u ü

To assist in solving the problems which we will consider, feature matrices of these segments are given below in (21).

(21)

	cns	son	syl	voi	cnt	nas	lat	ant	cor	hi	bck	low	rd
p	+	-	-	-	-	-	-	+	-	-	-	-	-
t	+	-	-	-	-	-	-	+	+	-	-	-	-
k	+	-	-	-	-	-	-	-	-	+	+	-	-
b	+	-	-	+	-	-	-	+	-	-	-	-	-
d	+	-	-	+	-	-	-	+	+	-	-	-	-
g	+	-	-	+	-	-	-	-	-	+	+	-	-
f	+	-	-	-	+	-	-	+	-	-	-	-	-
s	+	-	-	-	+	-	-	+	+	-	-	-	-
x	+	-	-	-	+	-	-	-	-	+	+	-	-
v	+	-	-	+	+	-	-	+	-	-	-	-	-
γ	+	-	-	+	+	-	-	-	-	+	+	-	-
w	-	+	-	+	+	-	-	-	-	+	+	-	+
y	-	+	-	+	+	-	-	-	-	+	-	-	-
l	+	+	-	+	+	-	+	+	+	-	-	-	-
m	+	+	-	+	-	+	-	+	-	-	-	-	-
n	+	+	-	+	-	+	-	+	+	-	-	-	-
a	-	+	+	+	+	-	-	-	-	-	+	+	-
e	-	+	+	+	+	-	-	-	-	-	-	-	-
i	-	+	+	+	+	-	-	-	-	+	-	-	-
o	-	+	+	+	+	-	-	-	-	-	+	-	+
u	-	+	+	+	+	-	-	-	-	+	+	-	+
ü	-	+	+	+	+	-	-	-	-	+	-	-	+

Each of the following sets of segments can be defined in terms of some set of distinctive features.

(22) i. p t k f s x
ii. p t b d f s v l m n
iii. w y l m n a e i o u ü
iv. p k b g f x v γ
v. y l m n a e i
vi. v γ w y a e i o u ü

In the first set, each segment is a voiceless obstruent, and, equally importantly, every voiceless obstruent of the language is included in this first set. This set could be specified as [-sonorant,-voice] or as [-voice], since all voiceless segments in the language are [-sonorant]. Given that both specifications refer to exactly the same segments (assuming the language has the segments of (20): if the language had [h], these two feature specifications would not describe the segment segments), there is no question of one solution being wrong in the technical sense. However, unless there is a compelling reason to do otherwise, the simplest definition of the set of segments should be given, using only those features which are absolutely necessary. The features which are used to exactly define a set of segments depends very much on what the entire set of segments in the language is. If we were dealing with a language which had, in addition, the segments [p^h t^h k^h] then in specifying the set [p t k f s x], one would have to also mention [-s.g.] in order to achieve a definition of the set which excludes [p^h t^h k^h].

Whether mention of a feature is required depends on the theory you use. One theory of assimilations requires the assimilating feature to be explicitly mentioned in a rule, even if it could be predicted on the basis of other features.

The set (22ii) contains only consonants (i.e. [-syllabic] segments), but it does not contain all of the [-syllabic] segments of the language. Compare the segments making up (22ii) with the full set of consonants:

(23) p t b d f s v l m n ← Selected class of segments
p t k b d g f s x v γ w y l m n ← Entire set of consonants

This set does not include glides: recall that [consonantal] is the essential property which distinguishes glides (including *h* and *ʔ*, which are lacking here) from regular consonants. Therefore, all of the segments in (ii) are [+consonantal]. But not all [+consonantal] segments are included in set (ii): the velars are not included, so we need a further restriction. The features typically used to specify velars are [+high, +back], so we can use one of those features. Thus, one can pick out the segments in (ii) as the class of [+consonantal,-high] segments, or the [+consonantal,-back] segments. Rather than refer to [consonantal], you could try to take advantage of the fact that all glides are [+high] and refer to (ii) as the set of [-high] segments, without mentioning [consonantal]. It is true that all segments in the set are [-high], but [-high] itself cannot be the entire description of this set since not all [-high] seg-

ments of the language are in the set: the vowels {aeo} is not in set (ii). We conclude that [+consonantal,-high] is the correct one for this class of segments.

Set (iii) contains a mixture of vowels and consonants: it includes all vowels, plus the nasals, the lateral [l], and the glides. This class is defined by [+sonorant]. Another feature which is constant in this group is [+voice], so you could define the class as [+sonorant,+voice]. But addition of [+voice] contributes nothing, so there is no point to mentioning that feature as well. Set (iv) on the other hand contains only obstruents, but not all obstruents. Of the whole set of obstruents, what is missing from (iv) is the group {tds}, which are [+coronal]. Therefore, we can refer to set (iv) by the combination [-sonorant,-coronal].

The fifth set, {ylmnaei}, includes a mixture of vowels and consonants. Some properties that members of this set have in common are that they are voiced, and they are sonorants. Given the phoneme inventory, all sonorants are voiced, but not all voiced segments are sonorants. Since the voiced obstruents {bdgvγ} are not included in this set, it would be less efficient to concentrate on the feature [+voice], thus we focus on the generalization that the segments are sonorants. Now compare this set to the total set of sonorants.

(24) y l m n a e i
w y l m n a e i o u ü

We can see that this set of segments is composed of a subset of sonorants, namely the sonorants excluding {w,o,u,ü}. But that set is the set of [+round] segments; therefore, the set is the set of [+sonorant,-round] segments.

The last set also contains a mixture of consonants and vowels: it includes all of the vowel and glides, plus the voiced obstruents {v,γ}. Therefore, the feature [sonorant] cannot be used to pick out this class of segments, since members of the class can have both values for that feature. However, all of the members of this class are voiced. Now compare set (vi) against the set of all voiced segments.

(25) v γ w y a e i o u ü
b d g v γ w y l m n a e i o u ü

The fundamental difference between [b] and [v], or between [g] and [γ], is that {bg} are stops while {vγ} are continuants. This suggests using [+contimuant] as one of the defining features for this class. Vowels and glides are all [+continuant], so we have passed the first test, namely that all segments in set (vi) are [+continuant,+voice]. We must also be sure that this is a sufficient specification for the class: are there any [+continuant,+voice] segments in the language which are not included in set (vi)? The segments to worry about in this case would be {lmn}, which are [+voice]. However, inspection of the chart of feature specifications given above indicates that these are all [-continuant].

As a further exercise in understanding how sets of segments are grouped by the features, assume a language with the following segmental inventory.

(26) p p^f t t^s č c k b b^v v β d^z ǰ ɟ g m n ŋ f θ s š d ð z ž i ü e ö ə o u a w y

For each group, determine what feature(s) define the particular set of segments.

(27) i. č c k ǰ ɟ g ŋ š ž i ü e ö ə o u a w y
ii. s i š e f z v β a ž o u y ö θ ü ə w ð
iii. k y g c w i u ü ɟ ŋ
iv. k g a ə ŋ

4. Possible Phonemes and Rules — an Answer

We now return to the theoretical questions raised at the beginning of this chapter, what is a possible phoneme and what is a possible phonological rule.

4.1. Possible Phonemes

The theory of features answers the question of possible phonemes, saying that the segments which can be constructed using these features are all and only the possible phonemes. This gives a mathematical upper limit of 2^n segments, given *n* binary features, so if there are 20 features (a reasonable number), there are 1,048,576 logically possible feature specifications, and this is quite a lot of segments. It also has to be physically possible to realize a segment, so the number of possible segments is smaller than this. Many segments can be imagined which are phonetically uninterpretable, such as one which is [+high,+low]. Such a segment is physically impossible since the tongue cannot be contradictorily raised and lowered at the same time, so the non-existence of a large class of such segments is independently explained. Similarly, no segment can be [+cons,-hi, -back,-ant,-cor]. A segment which is [+cons] is not a vowel or glide. The feature [-back] tells us that the segment would have a place of articulation in front of the velar position. [-Anterior] tells us that it must have a place of articulation behind the alveolar ridge, and [-hi] tells us that it cannot be a palatal. Everything about this description suggests the vowel [e], *except* that it is [+consonantal], whereas vowels are [-consonantal]. No major constriction can be formed with the tongue in the position of [e]: hence this combination of features happens to be physically impossible. To be attested in a language, a segment must be both *combinatorially* possible, i.e. uses the features given by the theory, and *physically* possible.

Although he set of attested phonemes in human languages is quite large, there are significant limitations on what phonemes are possible. Retroflex consonants have the features [-anterior, +coronal, -distributed]. Recall the question whether a language could contrast two kinds of retroflex consonants, such as apical

and sub-laminal retroflex as found in Hindi versus Telugu. According to this theory of features, such a contrast is impossible, since no feature is available to describe such a difference within a language. Dfferences across languages are possible because the process of phonetic interpretation is not subject to the same limitations as in phonological feature theory. Were we to discover such a contrast, the theory of features would be challenged, because it has no mechanism for expressing the distinction. Similarly, the differences attested in the phonetics of [u] and [ʊ] across languages are never found within a language. In a single language, the maximal contrast is between two such vowels, governed by the feature tense (or ATR). The fact that such differences exist at the phonetic level between languages, but are never exploited within a single language as a way to distinguish words, is an example of the difference between phonetic and phonological properties.

Thus one of the main goals of distinctive feature theory is providing a predictive framework for saying what contrasts will and will not be found in the phoneme systems of human languages.

4.2. Rule Formulation and Features

The most important function of features is to form the basis for writing rules, which is crucial in understanding what defines a possible phonological rule. A typical rule of vowel nasalisation, which nasalises all vowels before a nasal, can be formulated very simply if stated in features:

(28) [+syllabic] → [+nasal] / __ [+nasal]

Such a rule is common in the languages of the world. Very uncommon, if it exists at all, is one nasalising only the lax vowel [ɪ], and only before [m]. Formulated with features, that rule looks as follows:

(29) $$\begin{bmatrix} +\text{ syl} \\ -\text{ ATR} \\ +\text{ hi} \\ -\text{ round} \end{bmatrix} \rightarrow [+\text{nasal}] / \_\_\_ \begin{bmatrix} +\text{ nasal} \\ +\text{ ant} \\ -\text{ coronal} \end{bmatrix}$$

This rule require significantly more features than (28), since [ɪ] which undergoes the rule must be distinguished in features from other high vowels such as [i] or [ʊ] which (in this hypothetical case) do not undergo the rule, and [m] which triggers the rule must be distinguished from [n] or [ŋ] which do not.

Simplicity in rule writing. This relation between generality and simplicity on the one hand, and desirability or commonness on the other, has played a very impor-

tant role in phonology: all things being equal, simpler rules are preferred, both for the intrinsic elegance of simple rules and because they correlate with more general classes of segments. Maximum generality is an essential desideratum of science.

The idea that rules are stated in terms of the simplest, most general classes of phonetically defined segments has an implication for rule formulation. Suppose we encounter a rule where high vowels (but not mid and low vowels) nasalize before nasals stops (*n,m,ŋ*), thus *in* → *ĩn, uŋ* → *ũŋ* and so on. We could formulate such a rule as follows:

(30) $$\begin{bmatrix} +\text{syl} \\ +\text{hi} \end{bmatrix} \rightarrow [+\text{nasal}] \,/\, \_\_ \begin{bmatrix} +\text{nasal} \\ -\text{cont} \end{bmatrix}$$

However, we could equally well formalize the rule as

(31) $$\begin{bmatrix} +\text{syl} \\ +\text{hi} \\ -\text{low} \end{bmatrix} \rightarrow \begin{bmatrix} +\text{syl} \\ +\text{hi} \\ -\text{low} \\ +\text{nasal} \end{bmatrix} \,/\, \_\_ \begin{bmatrix} +\text{nasal} \\ -\text{cont} \\ -\text{low} \end{bmatrix}$$

We could freely add [-low] to the specification of the input segment (since no vowel can be [+hi,+low], thus high vowels automatically would pass that condition), and since the same class of vowels is referenced, inclusion of [-low] is empirically harmless. Saying that the vowel becomes [+syl,+hi,-low] is harmless, since the vowel that undergoes the change already mad these specifications. At the same time, the additional features in (31) are useless complications, so on the theoretical grounds of simplicity we formalise the rule as (30). In writing phonological rules, we specify only features which are mandatory. A formulation like

(32) $$[+\text{syl}] \rightarrow [+\text{nasal}] \,/\, \_\_ \begin{bmatrix} +\text{nasal} \\ -\text{cont} \end{bmatrix}$$

would mention fewer features, but it would be wrong, since the rule should state that only *high* vowels nasalise, and this rule nasalises *all* vowels.

Formalisability. The claim that rules are stated in terms of phonetically defined classes is essentially an axiom of phonological theory. What are the consequences of such a restriction? Suppose you encounter a language with a phonological rule of the type {p,r} → {i,b} / __ {o,n}. Since the segments being changed (*p* and *r*) or conditioning the change (*o* and *n*) cannot be defined in terms of any combina-

tion of features, nor can the changes be expressed via any features, the foundation of phonological theory would be seriously disrupted. Such a rule would refute a fundamental claim of the theory, that processes must be describable in terms of these (or similar) features. This is what it means to say that the theory makes a prediction: if that prediction is wrong, the theory itself is wrong.

Much more remains to be said about the notion of 'possible rule' in phonology; nevertheless, we can see that distinctive feature theory plays a vital role in delimiting possible rules, especially in terms of characterising the classes of segments that can function together for a rule. We now turn to a discussion of rule formalism, in light of distinctive feature theory.

5. The Formulation of Phonological Rules

Many aspects of rule theory were introduced in our informal approach to rule-writing, and they carry over in obvious ways to the formal theory that uses features. The general form of a phonological rule is

(33) $$\begin{bmatrix} \alpha F_i \\ \beta F_j \\ \vdots \end{bmatrix} \rightarrow \begin{bmatrix} \gamma F_k \\ \mu F_l \\ \vdots \end{bmatrix} \;/\; \cdots \begin{bmatrix} \theta F_m \\ \delta F_x \\ \vdots \end{bmatrix} \underline{\quad\quad} \begin{bmatrix} \kappa F_y \\ \lambda F_z \\ \vdots \end{bmatrix} \cdots$$

where F_i, F_j, F_k... are features and α, β, γ... are plus or minus values. The matrix to the left of the arrow is the segment changed by the rule; that segment is referred to as the **focus** or **target** of the rule. The matrix immediately to the right of the arrow is the **structural change**, and describes the way in which the target segment is changed. The remainder of the rule constitutes the **trigger** (also known as the **determinant** or **environment**), stating the conditions outside of the target segment which are necessary for application of the rule.

Each element is given as a matrix, which expresses a conjunction of features. The matrices of the target and trigger mean "all segments of the language which have the features [αF_i] as well as [βF_j]...". The matrix of the structural change means that when a target segment undergoes a rule, it receives whatever feature values are specified in that matrix.

There are a few special symbols which enter into rule formulation. One which we have encountered is the word boundary, symbolized as "#". A rule which lengthens a vowel before a word-final sonorant would be written as follows.

(34) [+syl] → [+long] / ___ [+son] #

A rule which devoices a word-initial consonant would be written as:

(35) [-son] → [-voice] / # ___

A word boundary can come between the target and the trigger segments, in which case it means "when the trigger segment is in the next word". Such processes are relatively infrequent, but for example there is a rule in Sanskrit which voices a consonant at the end of a word when it is followed by a sonorant in the next word, so /tat#aham/ becomes [tad#aham] "that I"; voicing does not take place strictly within the word, and thus /pat-a:mi/ "I fly" does not undergo voicing. This rule is formulated as in (36).

(36) [-son] → [+voice] / __ # [+son]

Another symbol is the null, ∅, used in the focus or structural change of a rule. As the focus, it means that the segment described to the right of the arrow is inserted in the stated context, and as the structural change it means that the specified segment is deleted. Thus a rule that deletes a word-final short high vowel which is preceded by a sonorant would be written as follows.

(37) $\begin{bmatrix} \text{+syl} \\ \text{-hi} \\ \text{-long} \end{bmatrix} \rightarrow \varnothing \ / \ [\text{+son}] \ \_\_ \ \#$

There are occasions where it is necessary to restrict a rule to apply only when a sequence occurs in different morphemes, but not within a morpheme. Suppose you find a rule that deletes a consonant after a consonant, but only when the consonants are in separate morphemes: thus the bimorphemic word /tap-ta/ with /p/ at the end of one morpheme and /t/ at the beginning of another becomes [tapa], but monomorphemic word /tapta/ does not undergo deletion. Analogous to the word boundary, there is also a morpheme boundary symbolised by "+", which can be used in writing rules. Thus the rule deleting the second of two consonants just in case the consonants are in diferent morphemes (hence a morpheme boundary comes between the consonants) is stated as:

(38) [-syl] → ∅ / [-syl] + ___

You may encounter other conventions of formalism. One such notation is the brace notation. Whereas the standard matrix [...] refers to a conjunction of properties — segments which are A *and* B *and* C all at once — braces {...} express disjunctions, that is, segments which are A *or* B *or* C. One of the most frequent uses of braces is exemplified by a rule found in a number of languages which shortens a long vowel if it is followed by either two consonants or else one consonant plus a word boundary, i.e. followed by a consonant that is followed by an consonant or #. Such a rule can be written as (39).

(39) $[+syl] \rightarrow [-long] \ / \ \_\_ \ [-syl] \begin{Bmatrix} [-syl] \\ \# \end{Bmatrix}$

Most such rules use the notation to encoding syllable related properties, so in this case the generalization can be restated as "shorten a long vowel followed by a syllable-final consonant". Using "." as the symbol for a syllable boundary, this rule could then be reformulated as:

(40) $[+syl] \rightarrow [-long] \ / \ \_\_ \ [-syl] \ .$

Although the brace notation has been a part of phonological theory, it has been viewed with considerable skepticism, partly because it is not well motivated for more than a handful of phenomena that may have better explanations (e.g. the syllable), and partly because it is a powerful device that undermines the central claim that rules operate in terms of natural classes (conjunctions of properties).

Some rules need to refer to a variably-sized sequence of elements. A typical example is vowel harmony, where one vowel assimilates a feature from another vowel, and ignores any consonants that come between. Suppose we have a rule where a vowel becomes round after a round vowel, ignoring any consonants. We could not just write the rule as (41), since that incorrectly states that only vowels strictly next to round vowels harmonise.

(41) $[+syl] \rightarrow [+rnd] \ / \ [+syl,+rnd] \ \_\_\_$

We can use the subscript-zero notation, and formalise the rule as in (42).

(42) $[+syl] \rightarrow [+rnd] \ / \ [+syl,+rnd] \ [-syl]_0 \ \_\_\_$

The expression "$[-syl]_0$" means "any number of [-syl] segments", from none to an infinite sequence of them.

A related notation is the parenthesis, which surrounds elements that may be present, but are not required. A rule of the form $X \rightarrow Y \ / \ \_\_ \ (WZ)Q$ means that X becomes Y before Q or before WZQ, that is, before Q ignoring WZ. The parenthesis notation essentially serves to group elements together. This notation is used most often for certain kinds of stress-assignment rules and advancements in the theory of stress have rendered parenthesis unnecessary in many cases.

One other very useful bit of notation is the feature variable notation. So far, it has actually been impossible to formalise one of the most common phonological rules in languages, the rule which assimilates a nasal in place of articulation to the following consonant, where /mk/ → [ŋk], /np/ → [mp] and so on. While we can write a rule which makes any nasal become [+ant,+cor] before a [+ant,+cor] consonant — any nasal becomes [n] before /t/ — and we can write a

rule to make any nasal [+ant,-cor] before a [+ant,-cor] consonant — nasals become [m] before [p] — we cannot express both changes in one rule.

(43) a. $$\begin{bmatrix}+\text{nas}\end{bmatrix} \rightarrow \begin{bmatrix}+\text{ant}\\+\text{cor}\end{bmatrix} / \_\_ \begin{bmatrix}+\text{ant}\\+\text{cor}\end{bmatrix}$$

b. $$\begin{bmatrix}+\text{nas}\end{bmatrix} \rightarrow \begin{bmatrix}+\text{ant}\\-\text{cor}\end{bmatrix} / \_\_ \begin{bmatrix}+\text{ant}\\-\text{cor}\end{bmatrix}$$

The structural change cannot be "→[+cor]" because when a nasal becomes [m] it becomes [-cor]. For the same reason the change cannot be "→[-cor]" since making a nasal becomes [n] makes it become [+cor]. One solution is the introduction of feature variables, notated with Greek letters α,β,γ etc. whose meaning is "the same value". Thus a rule which makes a nasal take on whatever values the following consonant has for place of articulation would be written as follows.

(44) $$[+\text{nas}] \rightarrow \begin{bmatrix}\alpha\text{ant}\\\beta\text{cor}\end{bmatrix} / \_\_ \begin{bmatrix}\alpha\text{ant}\\\beta\text{cor}\end{bmatrix}$$

Thus when the following consonant has the value [+cor] the nasal becomes [+cor] and when the following consonant has the value [-cor] the nasal becomes [-cor]. We will return to issues surrounding this notation in the final chapter.

There are a couple of commonly-used informal shorthand practices which you need to recognise. Many rules refer to "consonants" versus "vowels", meaning [-syllabic] and [+syllabic] segments, and the shorthand "C" and "V" are often used in place of [-syllabic] and [+syllabic]. Also, related to the feature variable notation, it is sometimes necessary to write rules which refer to the entire set of features. A typical example would be in a rule "insert a vowel which is a copy of the preceding vowel into a word-final cluster". Rather that explicitly listing every feature with an associated variable, such a rule might be written as:

(45) $\varnothing \rightarrow V_i \,/\, V_i\ C\_C\#$

meaning "insert a copy of the preceding vowel".

6. Changing the Theory

The theory of features is an empirical hypothesis, and is subject to revision in the face of appropriate data. It is not handed down by a higher authority, nor is it arbitrarily picked at the whim of the analyst. It is important to give critical thought

to how the set of distinctive features can be tested empirically, and revised. One prediction of the theory which we have discussed in section 4.1 is that the two kinds of phonetic retroflex consonants found in Hindi and Telugu can not contrast within a language. What would happen if a language were discovered which distinguished two degrees of retroflexion? Would we discard features altogether?

This situation has already arisen: the theory presented here evolved from earlier, similar theories. In an earlier theory proposed by Jakobson & Halle, retroflex consonants were described with the feature [flat]. This feature was also used to describe rounding, pharyngealisation and uvularization. While it may seem strange to describe so many different articulatory characteristics with a single feature, the decision was justified by the fact that these articulations share an acoustic consequence, a downward shift or weakening of higher frequencies. The assumption at that point was that no language could minimally contrast retroflexion, rounding, and pharyngealisation. If a language has both [ʈ] and [k^w], the surface differences in the realisation of [flat], as retroflexion versus rounding, would be due to language-specific spell-out rules.

The theory would be falsified if one could show that rounding and pharyngealisation are independent, and counterexamples were found. Arabic has the vowels [i a u] as well as pharyngealised vowels [$i^ˤ$ $a^ˤ$ $u^ˤ$], which derive by assimilation from a pharyngealised consonant. If rounding and pharyngealisation are both described by the feature [flat], it is impossible to phonologically distinguish [u] and [$u^ˤ$]. But this is not at all inappropriate if the goal is to represent phonological contrasts as opposed to phonetic differences, since the difference between [u] and [$u^ˤ$] is a low-level phonetic one.

Another prediction is that since uvular and round consonants are both [+flat], there should be no contrast between round and non-round uvulars, or between round velars and non-round uvulars, within a language. But a number of languages of the Pacific Northwest including Lushootseed have the contrast [k k^w q q^w]. The Dravidian language Badaga is reported to contrast plain and retroflex vowels, where any of the vowels [i e a o u] can be plain, half-retroflex, or fully retroflex.[6] If [flat] indicate both retroflexion and rounding, it would be impossible to contrast [u] and [u^w]. Since such languages actually do exist, their discovery forced the abandonment of the feature [flat] in favor of the system now used.

The specific feature [flat] was wrong, not the theory of features itself. Specific features may be incorrect, which will cause us to revise or replace them, but revisions should be undertaken only when strong evidence is presented which forces a revision. Features form the foundation of phonology, and revision to those features may lead to considerable changes in the predictions of the theory. Such

[6] Badaga's three-way vowel contrast challenges the standard theory as well. Little is known about this language: the contrast was originally reported by Emeneau 1939, and Ladefoged & Maddieson 1996 report that few speakers have a three-way contrast. The problem posed by this contrast has been acknowledged, but so far no studies have explored its nature.

changes should be undertaken with caution, taking note of unexpected consequences. If the theory changes constantly, with new features constantly being added, this would rightly be taken as evidence that the underlying theory is wrong.

Suppose we find a language with a contrast between regular and sublingual retroflex consonants. We could accomodate this hypothetical language into the theory by adding a new feature [sublingual], defined as forming an obstruction with the underside of the tongue. This theory makes a new set of predictions: it predicts other contrasts distinguished by sublinguality. We can presumably restrict the feature to the [+coronal] segments on physical grounds. The features which distinguish coronals subclasses are [anterior] and [distributed], which alone can combine to describe four varieties of coronal — which actually exist in a number of Australian languages. With a new feature [sublingual], eight coronal classes can be distinguished: regular and sublingual alveolars, regular and sublingual dentals, regular and sublingual alveopalatals, and regular and sublingual retroflex consonants. Yet no such segments have been found. Such predictions need to be considered, when contemplating a change to the theory.

Similarly, recall the problem of 'hyper-tense', 'plain tense', 'plain lax' and 'hyper-lax' high vowels across languages: we noted that that no more than two such vowels exist in a language, governed by the feature [tense]. If a language were discovered with three or four such high vowels, we could add a feature 'hyper'. But this makes the prediction that there could also be four-way contrasts among mid and low vowels. If these implications are not correct, the modification to the theory is not likely to be the correct solution to the problem. In general, addition of new features should be undertaken only when there is compelling evidence for doing so. The limited number of features actually in use is an indication of the caution with which features are added to the theory.

The case for labial. A classical case in point of a feature which was added in response to significant problems with the existing feature system is the feature [labial]. It is now accepted that feature theory should include this feature:

[labial]: sound produced with the lips

This feature was not part of the set of features proposed in Chomsky & Halle 1968. However, problems were noticed in the theory without [labial].

The argument for adding [labial] is that it makes rules better formulizable. It was noticed that the following types of rules, inter alii, are frequently attested (see Campbell 1974, Anderson 1974).

(46) a. $b \rightarrow w$ / __ C
b. $w \rightarrow b$ / [+nasal] __
c. $w \rightarrow v$
d. $i \rightarrow u$ / {p,b,m,w,u,o} ___

In the first three rules, the change from bilabial obstruent to rounded glide or rounded glide to labiodental obstruent is a seemingly arbitrary change, when written according to the then-prevailing system of features. There is so little in common between [b] and [w], given these features, that a change of [b] to [r] would be simpler to formulate as in (47b), and yet the change [b] → [r] is unattested.

(47) a. $\begin{bmatrix} +\text{ant} \\ -\text{cor} \\ +\text{voi} \end{bmatrix} \rightarrow \begin{bmatrix} -\text{ant} \\ -\text{cons} \\ +\text{high} \\ +\text{back} \\ +\text{rd} \end{bmatrix} / \_\_\ \text{C}$ b. $\begin{bmatrix} -\text{cons} \\ +\text{hi} \\ +\text{rd} \end{bmatrix} \rightarrow \begin{bmatrix} +\text{ant} \\ -\text{cor} \\ -\text{hi} \\ -\text{rd} \end{bmatrix}$

In the last rule of (46), no expression covers the class {p, b, m, w, u, o}: rather they correspond to the disjunction [+ant,-cor] or [+round].

These rules can be expressed quite simply with the feature [labial].

(48) a. $\begin{bmatrix} +\text{labial} \\ +\text{voi} \end{bmatrix} \rightarrow [-\text{cons}] / \_\_\_\ \text{C}$ b. $\begin{bmatrix} +\text{lab} \\ -\text{cons} \end{bmatrix} \rightarrow [+\text{cons}] / [+\text{nasal}]\ \_\_$

c. $\begin{bmatrix} +\text{labial} \\ +\text{round} \end{bmatrix} \rightarrow \begin{bmatrix} +\text{cons} \\ -\text{round} \end{bmatrix}$ d. $\text{i} \rightarrow [+\text{labial}] / [+\text{labial}]\ \_\_\_$

Feature redefinition. Even modifying definitions of existing features must be done with caution, and should be based on substantial evidence that existing definitions fail to allow classes or changes to be expressed adequately. One area where it is conceivable to modify a feature definition is that for [continuant]. The standard definition states that a segment is [+continuant] if it is produced with air continuously flowing through the *oral cavity*. An alternative definition is that a segment is [+continuant] if air flows continuously through the *vocal tract*. How do we decide which definition is correct? The difference is that under the first definition, nasals are [-continuant] and under the second definition, nasals are [+continuant].

If the first definition is correct, we expect to find a language where {p, t, č, k, m, n, ŋ, b, d, ǰ, g} undergo or trigger a rule, and {f, s, θ, x, v, z, ð, γ} do not: under the "oral cavity" definition, [-continuant] refers to the class of segments {p, t, č, k, m, n, ŋ, b, d, ǰ, g}. On the other hand, if the second hypothesis is correct, we should find a language where {n, m, n, f, s, x, v, x, γ} undergo or trigger a rule, and the remaining consonants {p, t, k, b, d, g} do not: under the "vocal tract"

definition of [continuant], the feature specification [+continuant] would refer to the set {n, m, n, f, s, x, v, x, γ}.

Just as important as knowing what sets of segments can be referred to by one theory or another, you need to consider what groupings of segments *cannot* be expressed in a theory. Under either definition of [continuant], finding a process which refers to {p, t, k, b, d, g} proves nothing, since either theory can refer to this class, either as [-continuant] in the "oral cavity" theory or as [-continuant,-nasal] in the "vocal tract" theory. The additional feature needed in the "vocal tract" theory does complicate the rule, but that does not in itself disprove the theory. If you find a process referring to {n, m, n, f, s, x, v, x, γ}, excluding {p, t, k, b, d, g}, this would definitively argue for the "oral cavity" theory. Such a class can be referred to with the specification [+continuant] in the "oral cavity" theory, but there is no way to refer to that set under the "vocal tract" theory. As it stands, we have not found such clear cases: but, at least we can identify the type of evidence needed to definitively choose between the theories. The implicit claim of feature theory is that it would be impossible for both kinds of rules to exist in human languages. There can only be one definition of any feature, if the theory is to be coherent.

Central vowels. We will consider another case where the features face a problem with expressing a natural class, relating to the treatment of central versus back vowels. In Chapter 3 we saw that Kenyang, [k] and [q] are in complementary distribution, with [q] appearing word-finally after the vowels [o], [ɔ] and [a] and [k] appearing elsewhere. Representative examples are reproduced here.

(49)	enɔ**q**	'tree'	eno**q**	'drum'
	ŋgɑ**q**	'knife'	e**k**ɑ**q**	'leg'
	mə**k**	'dirt'	nde**k**	'European'
	pɔbri**k**	'work project'	ɑyu**k**	(person's name)

Phonetic descriptions of vowels are not usually based on physiological data such as x-ray studies. Tongue positions are often deduced by matching sound quality with that of a standardly defined vowel: we assume that Kenyang schwa is central because it sounds like schwa, which is defined as being central.

Schwa does not cause lowering of *k* to *q*. In the standard account of vowels, [ə] differs from [ɔ] only in rounding, though phonetic tradition claims that these vowels also differ in being back ([ɔ]) versus central ([ə]). As previously discussed, this difference is attributed to a low-level, phonologically insignificant phonetic factor.

The problem which Kenyang poses is that it is impossible to formulate the rule of k-lowering if schwa is phonologically a mid back unrounded vowel. A simple attempt at formulizing the rule would be:

(50) $$\begin{bmatrix} +\text{hi} \\ +\text{back} \end{bmatrix} \rightarrow \begin{bmatrix} -\text{high} \end{bmatrix} / \begin{bmatrix} +\text{back} \\ -\text{high} \end{bmatrix} \_\_$$

If schwa is [+back,-hi,-round] it would satisfy the requirements of the rule so should cause lowering of /k/, but it does not: therefore this formulation cannot be

correct. Since schwa differs from [ɔ] in being [-round], we might try to exclude [ə] by requiring the trigger vowel to be [+round].

(51) $$\begin{bmatrix} + \text{hi} \\ + \text{back} \end{bmatrix} \rightarrow \begin{bmatrix} - \text{high} \end{bmatrix} / \begin{bmatrix} + \text{back} \\ - \text{high} \\ + \text{round} \end{bmatrix} \_\_$$

But this formulation is not correct either, since it would prevent the non-round low vowel [ɑ] from triggering uvularization, which in fact it does do.

These data are a problem for the theory that there is only a two-way distinction between front and back vowels, not a three-way distinction between front, central and back vowels. The uvularization rule of Kenyang can be formulated if we assume an additional feature, [±front], which characterises front vowels. Under that theory, back vowels would be [+back,-front], front vowels would be [+front, -back], and central vowels would be [-back,-front]. Since we must account for this fact about Kenyang, the theory must be changed. But before adding anything to the theory, it is important to consider all of the consequences of the proposal.

A positive consequence is that it allows us to account for Kenyang. Another possible example of the relevance of central vowels to phonology comes from Norwegian (and Swedish). There are three high, round vowels in Norwegian, whereas the standard feature theory countenances the existence of only two high rounded vowels, one front and one back. Examples in Norwegian spelling are *do* 'outhouse', *du* 'you sg.' and *dy* 'forbear!'. The vowel *o* is phonetically [u], and *u* and *y* are distinct non-back round vowels. In many IPA transcriptions of Norwegian, these are transcribed as [dʉ] 'you sg.' and [dy] 'forbear!', implying a contrast between front, central and back round vowels. This is exactly what the standard view of central vowels has claimed should not happen, and it would appear that Norwegian also falsifies the theory.

The matter is not so simple. The vowels spelled *u* versus *y* also differ in lip configuration. The vowel *u* is 'in-rounded', with an inward narrowing of the lips, whereas *y* is 'out-rounded', with an outward-flanging protrusion of the lips. This lip difference is hidden by the selection of the IPA symbols [ʉ] versus [y]. While it is clear that the standard theory does not handle the contrast, we cannot tell what the correct basis for maintaining the contrast is. We could treat the difference as a front ~ central ~ back distinction and disregard the difference in lip configuration (leaving that to phonetic implementation); or, we could treat the labial distinction as primary and leave the presumed tongue-position to phonetic implementation.

Given that the theory of features has also accepted the feature [labial], it is possible that the distinction lies in [labial] versus [round], where the out-rounded vowel <y> is [+round, +labial] and in-rounded <u> is [-round, +labial] — or vice versa. Unfortunately, nothing in the phonological behavior of these vowels gives any clue as to the natural class groupings of the vowels, so the problem of representing these differences in Norwegian remains unresolved. Thus the case for

positing a distinct phonological category of central vowel does not receive very strong support from the vowel contrasts of Norwegian.

A negative consequence of adding [front], which would allow the phonological definition of a class of central vowels, is that it defines unattested classes and segments outside of the realm of vowels. The classical features could distinguish just [k] and [k^y], using [±back]. With the addition of [front], we would have a three-way distinction between k-like consonants which are [+front, -back], [-front, -back] and [-front, +back]. But no evidence at all has emerged for such a contrast in any language. Finally, the addition of the feature [front] defines a natural class [-back] containing front and central vowels, but not back vowels: such a class is not possible in the classical theory, and also seems to be unattested in phonological rules. This may indicate that the feature [front] is the wrong feature — at any rate it indicates that further research is necessary, in order to understand all of the ramifications of various possible changes to the theory.

Thus the evidence for a change to feature theory, made to handle the problematic status of [ə] in Kenyang phonology, would not be sufficiently strong to warrant complete acceptance of the new feature. We will suspend further discussion of this proposal until later, when non-linear theories of representation are introduced and answers to some of the problems such as the unattested three-way contrast in velars can be considered. The central point is that changes in the theory are not made at will: they are made only after considerable argumentation and evidence that the existing theory is fundamentally inadequate.

Summary

Language sounds can be defined in terms of a small set of universal phonetically-based features, which not only define the basic atoms of phonological representations, but also play a central role in the formal expression of rules. An important theme of this chapter is the nature of scientific theories, such as the theory of features, which make predictions both about what can happen and what cannot happen. The fundamental role of feature theory is to make specific predictions about the kinds of segments and rules that we should find in human languages. One of the main concerns of phonological theory is finding the correct set of features that define the sounds and rule systems of all human languages.

Exercises

1. Assume a segmental inventory composed of: [ʕ k t d s z n p f b i u e o a w h]. Indicate what feature or features characterize the following classes of sounds.

i. ʕ k u o a w
ii. f p k h
iii. f p b t s d z n
iv. ʕ u o w a b d z n i e
v. i z n e d

2. Given the segments [w y h ʔ i ɛ a o ɔ u m̩ l r m ŋ p t k^y k q b ð d d^y g γ], describe the following segment classes, being as economical as you can with your use of features.

i. m̩ l r m ŋ p t k^y k q b ð d d^y g γ
ii. w y i ɛ a o ɔ u m̩ l r m ŋ
iii. w a o ɔ u ŋ k q g γ
iv. w y h i ɛ a o ɔ u l r ð γ
v. y i ɛ a l r ŋ ð d d^y g γ
vi. y i k^y d^y
vii. i ɛ a o ɔ u m̩

3. Assume a language with the following segmental inventory:

p t t^s č c k φ f θ s š x b d d^z ǰ ɟ m n ŋ l i e o u a ü ö w y

(In this case, <c> represents a palatal stop, assumed to be featurally identical to a palatalized *k*). In each of the following groups, one of the segments is not a member of the natural class which the other sounds belong to. Identify that sound, and state what features characterise the remaining class of segments.

i. t č c š ǰ ɟ i e ü ö y
ii. t t^s č θ s š d d^z ǰ ɟ n l
iii. c k x ǰ ɟ ŋ i u ü w y
iv. k x ŋ o u a w y
v. p φ f b m l o u ü ö w

4. Based on the segmental inventory [p t k b d m n γ φ f s l a i o u y], characterise the following segments or groups of segments uniquely using the fewest features possible.

i. γ
ii. i
iii. n
iv. b,d
v. a,o
vi. o,u

5. State all of the features which are changed in each of the following rules.

i. p → f
ii. t → ŋ
iii. o → w
iv. k → s
v. s → t
vi. a → i

6. Formalise the following rules using distinctive features (segmental inventories to be assumed for each language are given in brackets).

i.	b,d,g → β,ð,γ / V __	[p t k b d g β ð γ m n ŋ r i u a ə]
ii.	p,k,q → β,γ,ʁ/ V ___	[p t č ṭ k q β r ž γ ʁ m i ĩ e ẽ æ o u ũ]
iii.	∅ → y / i,e __ o,u,a	[p t k b d n y w i ü e æ o u a]
iv.	t → s / __i	[p t k h v d s r l m n y i ü e ö a o u]
v.	s → r / V__V	[p t k b d g s r l m n h w y e i o u a]

7: Review previous solutions to exercises which you have done in the preceding chapters, and state the rules according to the features given here: discuss any problems which you may encounter in reformalising these rules.

Advanced Topics and Readings

A very detailed theory of speech articulation and the articulatory classification of sounds was developed nearly three millenia ago by the ancient Sanskrit grammarians. Their main concern was the accurate preservation of the language of the Vedas, whose correct pronunciation was deemed essential to the proper working of the incantations. Modern Western linguistics begins with Sir William Jones' celebrated paper in 1786 on the relationship of Sanskrit to Latin, Greek and Germanic. Jones, a pre-eminent Orientalist, had an extensive knowledge of Sanskrit

and the phonetic theories of the Indian phoneticians, and thanks to the introduction of Indian scholarship through people like Jones, that tradition significantly influenced western linguistics. Ancient Indian phonetic theory identified many phonetic categories that are familiar today, such as ‘articulator, ‘vowel’, ‘voice’: see Allen 1953 for discussion of the Indian Phoneticians.

In addition to a descriptive phonetic tradition, the Indian grammarians developed a system of grammatical rules — a generative system, in the sense of Chomsky 1957 — culminating in the Aṣṭādhyāyī of Pāṇini. Pāṇini presents an algebraic system of sound classification, one serving the needs of a set of phonological rules in his grammar, in the form of the *Sivasūtras*, a clever 14-line listing of the segments of Sanskrit which reads as:

> a-i-uṇ; ṛ-ḷk; e-oṇ; ai-auc; ha-ya-va-raṭ; laṇ; ña-ma-ṇa-ṇa-nam; jha-bhañ; gha-ḍha-dhaṣ; ja-ba-ga-ḍa-daç; kha-pha-cha-ṭha-tha-ca-ṭa-tav; ka-pay; ça-ṣa-sar; hal

This presentation of sounds reflects their grouping in rules (which reflects phonetic properties), and the consonant at the end of each line indicates the end of a group. While the grouping is not a perfect mirror of phonetic properties, you can see that the nasals are grouped together, as are the voiced consonants, the stops vs. fricatives vs. sonorants; place of articulation is also reflected in the ordering, though not in a trivial way.

Natural classes of sounds which undergo or trigger rules are encoded by mentioning the first sound in the class and the final consonant at the end of the class. Sanskrit has a rule that syllabic /i u ṛ ḷ/ become nonsyllabic [y w r l] before a vowel or diphthong, stated in the Aṣṭādhyāyī as “ik-o yaṇ ac-i”, literally “instead of the class ‘ik’ there is the class ‘yaṇ’ before the class ‘ac’.”. The class ‘ik’ is defined, referring to the first two lines, as everything from [i] through [ḷ] (the sound before the terminator ‘k’) thus /i u ṛ ḷ/, and ‘ac’ means everything from [a] to the terminator ‘c’, meaning [a i u ṛ ḷ e o ai au], viz. all syllabics.

In western linguistics, phonetics, which is the fountainhead of distinctive features, developed through the research of Sievers, Sweet, Jespersen, Jones and others, and phonology is rooted in Sweet’s 1887 distinction between sounds that depend on their environment — allophones — and sounds that can establish word differences. N. S. Trubetzkoy, one of the founders of the Prague School of Linguistics, was one of the major influences in the development of contemporary feature theory. Trubetzkoy 1939 looks beyond the physical aspect of language sound and focuses on how phonetic properties function in a language to define a system of phonological contrasts (oppositions, in his terminology). His taxonomy includes classifications such as bilateral vs. multilateral oppositions, proportional vs. isolated, constant and neutralizable oppositions, as well as privative, gradual and equipollent oppositions. The concept of neutralization is at the heart of phonologi-

cal analysis: we seek to uncover the underlying, non-neutralized nature of sounds when we analyse a set of alternations.

Two other concepts, *marked* and *privative*, play an important role in phonological theory. For Trubetzkoy, in a privative opposition one member (for example *p* in the pair *p, b*) lacks a phonetic mark — voicing — and the other one has the phonetic mark — it is the marked member. The concept of markedness has played a major role in generative grammar (see Chomsky & Halle 1968, Kean 1975, Battistella 1990, 1996), and has taken on a rather different meaning, as being "uncommon" or "at a formal disadvantage". In Optimality Theory (McCarthy 2002) the concept of a "markedness constraint" can be interpreted as "well-formedness constraint". While the theory of distinctive features presented here with plus and minus values for features views features as being equipollent (two equal values), more recent research especially given underspecification theory and feature geometry (see below) supports a privative view of some features, e.g. *b* being marked with the single-valued feature [voiced] and *p* having no specification for voicing.

The related concern of the Praguean linguist Roman Jakobson was the question of possible contrasts in human language, and in collaboration with Morris Halle and Gunnar Fant (Jakobson, Fant & Halle 1952; Jakobson & Halle 1956) he developed the theory of distinctive features. This research identified 12 to 15 features which were claimed to handle all phonological contrasts in human languages. We noted that the Jakobsonian features were typically defined in terms of acoustic properties rather than articulatory ones. Another significant contribution of this theory was to give all features two values, plus and minus. Rather than a gradual (scalar) opposition of vowel height with four values, the Jakobsonian system defined vowel height by two features [diffuse] (≈[high]) and [compact] (≈[low]) which says whether there is a concentration of acoustic energy in the central region.

The version of feature theory presented here is an adaptation of Chomsky & Halle 1968 — the so-called SPE features — which was the next step in the development of feature theory, and still serves as a theoretical baseline for current work on features. The differences between the SPE features and the Jakobson & Halle features are more along the lines of a refinement. Greater attention was given to the articulatory definition of features in the SPE system, and the features themselves were revised and expanded in a number of ways. In the course of a decade of research on phonology, a number of inadequacies in the Jakobsonian system were uncovered, for example the existence of non-strident affricates which posed a problem for the earlier theory of affricates, or the discovery that [flat] was inadequate as a model of retroflex, round, uvular and pharyngeal consonants, and these are addressed in the SPE feature system.

The SPE theory of features differed from its predecessors in a significant way, that rather than being designed just to handle phonemic contrasts, it is intended to describes all linguistic phonetic properties:

> The total set of features is identical with the set of phonetic properties that can in principle be controlled in speech; they represent the phonetic capabilities of man and, we would assume, are therefore the same for all languages. (p. 294-5)

Binarity of features is assumed for lexical entries but not throughout the grammar: they state (p. 297) that "the phonetic features are physical scales and may thus assume numerous coefficients, as determined by the rules of the phonological component", and certain rules in SPE operate in terms of specified numeric stress coefficients. See Clifton 1976 and Johnson 1981 and references therein for examples of phonetic implementation rules stated with numeric coefficients.

Certain features are proposed tenatively in SPE but were not generally adopted, including [suction], [pressure] and a distinction between [delayed primary release] i.e. [delayed release] for affricates, and [delayed secondary release] which is primarily relevant for clicks — see Sagey 1986 for a reanalysis of click "effluxes". The SPE feature [covered] is the same as Advanced Tongue Root. Halle & Stevens 1971 introduce the features [c.g.] and [s.g.], replacing [heightened subglottal pressure], [pressure] and, in part, [suction], and also introduce two features [stiff vocal cords] and [slack vocal cords] to describe voicing. Other features have been argued for after the publication of SPE, most notably [labial] (Anderson 1974, Campbell 1974) and [grave] (Odden 1978). See Keating 1988 for a detailed overview of distinctive features in the post-SPE era.

A major change in phonlogy began in the mid 1970's with research by Leben, Goldsmith, Clements and others on the representation of tone. The autosegmental model of representation, discussed in Chapter 11, was proposed to resolve an accretion of technical problems with the standard SPE model especially as it applied to tone. The proposal was made that features organised into smaller subsegmental units, which function like whole segments (segments in their own right, i.e. auto-segments). In the first decade of autosegmental phonology, the features remained largely those of SPE though each feature had a formal independence from other features, in that feature specifications and segments are not in a 1-to-1 relationship as they are in SPE-style representations.

One outgrowth of autosegmental theory was that prosodic properties — length, syllabicity and stress — were reconceptualised as herarchical structural properties in a separate representational dimension. thus outside the domain of feature theory. Accordingly, 'syllabic' is the suprasegmental relation of being the 'peak' (or non-peak) in a syllable; length is represented by a separation of segmental content and 'timing' where long segments have two timing units and short segments have one; stress is a rhythmic prominence relation between syllables in a word so that one syllable is stronger than another. See Broselow 1995, Blevins 1995, Hayes 1995 for further details. The features for tone, which were never de-

veloped in SPE, are a matter of current debate: see Clements 1983, Pulleyblank 1986, Hyman 1993, Bradshaw 1999.

Two recurring ideas which were part of the autosegmental theory resulted in a significant change in feature theory. One was the realisation that while all features are independent of others, there are still valid multi-feature units, thus the features for place of articulation can function as a unit in rules: in other words, there is a constituent structure to feature relations. This resulted in the theory of Feature Geometry, discussed in Chapter 11, which has also resulted in the adoption of certain new features, especially for place of articulation.

The second idea was that not all segments have values for each feature. It was particularly obvious for tone that vowels but not consonants have tone, and it was sometimes difficult to formulate tone rules correctly if consonants get in the way. A similar problem is often observed in vowel harmony, where consonants typically are completely irrelevant to assimilations between vowels, and for that matter vowels are usually irrelevant to (less frequent) long-distance consonantal assimilations. The problem of material intervening between target and trigger was a long-standing one in phonology (see Howard 1972, Jensen 1973, Odden 1977, 1994), and autosegmental representations coupled with Underspecification Theory (Archangeli 1988, Steriade 1995) provided a formal context for saying that consonants do not matter for vowel harmony because consonants and vowels are usually specified with different features.

7

Doing an Analysis

This chapter explores a subset of the phonologies of a number of languages. The purpose of this chapter is to make explicit the reasoning typically applied to the task of solving a phonology problem. By studying models of problem solving, you not only better understand the logic of problem solving, but you also gain experience with rules and issues regarding underlying representations encountered in the languages of the world.

Analyzing a system of phonological alternations is not trivial: it requires practice, where you gain experience by solving phonological problems of increasing complexity, experience which facilitates subsequent problem solving. The wider your experience is with actual phonological processes and problem solving, the better able you will be to appreciate what processes are common in the languages of the world, and to understand the dynamics of hypothesis formation, testing and revision. The first analyses given here will be more explicit about the reasoning that goes into solving data sets of this nature, in some cases deliberately going down the wrong analytical path, so that you have the opportunity to recognise the wrong path, and see how to get back on the right path. In practice, many of the calculations that are involved here are done without explicitly thinking about it — once you have suitable experience with problem solving.

1. Yawelmani

Our first problem involves alternations in the verb paradigm in the Yawelmani dialect of Yokuts.

1.1. The data

Three phonological rules will be motivated by the following examples: vowel epenthesis, vowel shortening, and vowel harmony. In addition, it is not obvious what the underlying representation of verb roots is.

(1)

nonfuture	*imperative*	*dubitative*	*passive aorist*	
xathin	xatk'a	xatal	xatit	eat
dubhun	dubk'a	dubal	dubut	lead by hand
xilhin	xilk'a	xilal	xilit	tangle
k'oʔhin	k'oʔk'o	k'oʔol	k'oʔit	throw
doshin	dosk'o	do:sol	do:sit	report
ṣaphin	ṣapk'a	ṣa:pal	ṣa:pit	burn
lanhin	lank'a	la:nal	la:nit	hear
mek'hin	mek'k'a	me:k'al	me:k'it	swallow
wonhin	wonk'o	wo:nol	wo:nit	hide
p'axathin	p'axatk'a	p'axa:tal	p'axa:tit	mourn
hiwethin	hiwetk'a	hiwe:tal	hiwe:tit	walk
ʔopothin	ʔopotk'o	ʔopo:tol	ʔopo:tit	arise from bed
yawalhin	yawalk'a	yawa:lal	yawa:lit	follow
paʔiṭhin	paʔiṭk'a	paʔṭal	paʔṭit	fight
ʔilikhin	ʔilikk'a	ʔilkal	ʔilkit	sing
logiwhin	logiwk'a	logwol	logwit	pulverize
ʔugunhun	ʔugunk'a	ʔugnal	ʔugnut	drink
lihimhin	lihimk'a	lihmal	lihmit	run
ʔayiyhin	ʔayiyk'a	ʔayyal	ʔayyit	pole a boat
t'oyixhin	t'oyixk'a	t'oyxol	t'oyxit	give medicine
luk'ulhun	luk'ulk'a	luk'lal	luk'lut	bury
so:nilhin	so:nilk'a	sonlol	sonlit	put on back
ʔa:milhin	ʔa:milk'a	ʔamlal	ʔamlit	help
mo:yinhin	mo:yink'a	moynol	moynit	become tired
ṣa:lik'hin	ṣa:lik'k'a	ṣalk'al	ṣalk'it	wake up

1.2. The first step: morphology

First we need a morphological analysis of the data. In a simple case, this involves looking at columns and rows of data and figuring out which subparts of words are consistently present with one meaning, and which other subparts are consistently present with other meanings. This task is more complicated when the surface shape of roots and affixes changes by phonological rules. We cannot provide a definitive morphological analysis of these data without knowing what the phonological system is, and certainty as to the phonological rules is impossible without knowing the morphological analysis. We break out of this seeming circle by adopting — and constantly revising — a preliminary and less precise analysis of the phonology and morphology. Improvement in the underlying representations should result in better rules, and as we refine the system of rules, the nature of the underlying distinctions hopefully becomes clearer.

In this case, four suffixes are added to roots, *-hin* ~ *-hun* 'nonfuture', *-k'a* ~ *-k'o* 'imperative', *-al* ~ *-ol* 'dubitative' and *-it* ~ *-ut* 'passive aorist'. The notation

-hin ~ *-hun* indicates that the suffix is pronounced either as *-hin* or as *-hun*. We need to discover when one form vs. the other is used, and express that relation in terms of an underlying form and a rule changing the underlying form.

Stem variants. Some stems have only one surface shape — *xat-* 'eat', *dub-* 'lead by hand', *xil-* 'tangle', and *k'oʔ-* 'throw', so the most natural assumption would be that these *are* the underlying forms for these particular stems (this assumption may turn out to be wrong, but it is a good starting assumption). Most stems in the data-set have two surface manifestations. An important first step in understanding the rules of the language is to identify the alternations in the data, and one way to make the alternations explicit is to list the phonetic variants of each stem.

(2)

dos ~ do:s	'report'	ṣap ~ ṣa:p	'burn'
lan ~ la:n	'hear'	mek' ~ me:k'	'swallow'
won ~ wo:n	'hide'	p'axat ~ p'axa:t	'mourn'
hiwet ~ hiwe:t	'walk'	ʔopot ~ ʔopo:t	'arise from bed'
yawal ~ yawa:l	'follow'	paʔiṭ ~ paʔṭ	'fight'
ʔilik ~ ʔilk	'sing'	logiw ~ logw	'pulverize'
ʔugun ~ ʔugn	'drink'	lihim ~ lihm	'run'
ʔayiy ~ ʔayy	'pole a boat'	t'oyix ~ t'oyx	'give medicine'
luk'ul ~ luk'l	'bury'	so:nil ~ sonl	'put on back'
ʔa:mil ~ ʔaml	'help'	mo:yin ~ moyn	'become tired'
ṣa:lik' ~ ṣalk'	'wake up'		

In these cases, decisions must be made regarding the underlying forms.

Suffix variants. We must decide what the underlying form of each suffix is, and they all have two surface variants in terms of their vowel: either a nonrounded vowel, or a rounded vowel. For each suffix, we group the verbs in terms of which variant of the suffix is used with them.

(3)

-hin:	xat, xil, k'oʔ, dos, ṣap, lan, mek', won, p'axat, hiwet, ʔopot, yawal, paʔiṭ, ʔilik, logiw, lihim, ʔayiy, t'oyix, so:nil, ʔa:mil, mo:yin, ṣa:lik'
-hun:	dub, ʔugun, luk'ul
-k'a:	xat, dub, xil, ṣap, lan, mek', p'axat, hiwet, yawal, paʔiṭ, ʔilik, logiw, ʔugun, lihim, ʔayiy, t'oyix, luk'ul, so:nil, ʔa:mil, mo:yin, ṣa:lik'
-k'o:	k'oʔ, dos, won, ʔopot
-al:	xat, dub, xil, ṣa:p, la:n, me:k', p'axa:t, hiwe:t, yawa:l, paʔṭ, ʔilk, ʔugn, lihm, ʔayy, luk'l, ʔaml, ṣalk'

-*ol*:	k'oʔ, do:s, wo:n, ʔopo:t, logw, t'oyx, sonl, moyn
-*it*:	xat, xil, k'oʔ, do:s, ṣa:p, la:n, me:k', wo:n, p'axa:t, hiwe:t, ʔopo:t, yawa:l, paʔṭ, ʔilk, logw, lihm, ʔayy, t'oyx, sonl, ʔaml, moyn, ṣalk'
-*ut*:	dub, ʔugn, luk'l

1.3. Identifying phonological regularities

Vowel harmony. Having grouped the examples in this fashion, a phonological regularity can be detected. For the suffix *hin* ~ *hun*, the vowel *u* appears when the preceding vowel is *u*, and *i* appears in the suffix after any other vowel. The suffix *it* ~ *ut* obeys this same rule. The suffixes *k'a* ~ *k'o* and *al* ~ *ol* have the vowel *o* after *o*. This can be explained by positing a rule of vowel harmony between the suffix vowel and whatever vowel precedes it, where /a/ assimilates to /o/ and /i/ assimilates to /u/.

(4) $$\begin{bmatrix} \text{V} \\ \alpha\text{hi} \end{bmatrix} \rightarrow [+\text{round}] / \begin{bmatrix} \text{V} \\ \alpha\text{hi} \\ +\text{round} \end{bmatrix} \text{C}_0 \_\_\_$$

The variable notation — αhi.... αhi.... — expresses the condition that the vowels must have the same value of [hi], i.e. the harmonizing vowel must be [+hi] after a [+hi] round vowel, and [-hi] after a [-hi] round vowel, in order for the harmony rule to apply.

Vowel shortening. The next problem to tackle is the variation in the shape of the stem. A useful next step in trying to analyze that variation is to see whether the variants can be arranged into a small number of groups, organized according to the nature of the difference between the two stem shapes. In looking for such an organization, notice that some stems alternate in terms of having long versus short vowels, and in terms of having versus lacking a second vowel. Accordingly, we organize the data into the following classes of stem alternations (including the class of stems which have no alternation).

(5)	*CVC* —	xat, dub, xil, k'oʔ
	CVC ~ *CV:C* —	dos ~ do:s, ṣap ~ ṣa:p, lan ~ la:n, mek' ~ me:k', won ~ wo:n
	CVCVC ~ *CVCV:C* —	p'axat ~ p'axa:t, hiwet ~ hiwe:t, ʔopot ~ ʔopo:t, yawal ~ yawa:l

CVCVC ~ CVCC —	paʔiṭ ~ paʔṭ, ʔilik ~ ʔilk, logiw ~ logw, ʔugun ~ ʔugn, lihim ~ lihm, ʔayiy ~ ʔayy, t'oyix ~ t'oyx, luk'ul ~ luk'l
CV:CVC ~ CVCC —	so:nil ~ sonl, ʔa:mil ~ ʔaml, mo:yin ~ moyn, ṣa:lik' ~ ṣalk'

The initial hypothesis is that the invariant CVC stems have the underlying shape CVC. If there is no reason to make the underlying form be different from the surface form, the two forms should be assumed to be identical. Building on that decision, we will now set forth a hypothesis for stems which vary in shape between CVC and CV:C. It is highly unlikely that these stems also have the underlying shape CVC, since that assumption would make it very difficult to account for the first group of stems such as /xat/ which are invariant CVC. We would be unable to decide whether a stem vowel is supposed to have a length alternation, or not, so the reasoning that leads to hypothesizing the underlying distinction /xat/ vs. /do:s/ which is contextually neutralized is exactly the same as that which leads to hypothesizing that in Russian (discussed in Chapter 4) "time" is underlyingly /raz/ and "forest" is /les/.

Given the conclusion that stems like *do:s ~ dos* have an underlying CV:C form, under what circumstance is the underlyingly long vowel of the stem shortened? Taking /do:s/ as a representative, and mechanically combining the assumed underlying stem with what we take to be the underlying form of the suffix, we arrive at the following underlying and surface relations.

(6)					
	underlying	do:s-hin	do:s-k'a	do:s-al	do:s-it
	surface	doshin	dosk'o	do:sol	do:sit

The change of /a/ to [o] is due to vowel harmony. There is also a change in vowel length before *k'a* and *hin*, and not before *-al* and *-it*. These suffixes are distinguished by whether they begin with a consonant or a vowel, thus whether combining the stem and suffix would result in the sequence V:CC. Scanning the entire data set reveals an important generalization, that a long vowel is always followed by CV, that is, a long vowel only occurs in an open syllable. The discovery of this generalization allows us to posit the following vowel shortening rule.

(7) V → [-long] / __ CC

This rule is all that is needed to explain both the invariant CVC stems and the alternating CV:C ~ CVC stems. The existence of this rule also explains why we do not find the surface sequence V:CC — a long vowel before a cluster of two consonants — anywhere in the data, as such sequences undergo vowel shortening.

We turn next to the stems with the shape CVCVC ~ CVCV:C such as *p'axat ~ p'axa:t*. Since we have already encountered a rule which accounts for al-

ternations in vowel length, we should immediately suspect that this length alternation is the same as the one just accounted for in CV:C ~ CVC stems. When we inspect the contexts where the long-vowel variant occurs, we see that there are long vowels when a vowel initial suffix is added, and short vowels when a consonant initial suffix is added. In other words, these stems are virtually the same as /CV:C/ stems, except that they have the underlying shape /CVCV:C/. We initially hypothesized that there was a rule of vowel shortening based on /CV:C/ stems, and that rule nicely handled those data. The way we formulated that rule was quite general, since it only said "shorten a long vowel before two consonants". Such a statement predicts that, if there are other stem shapes such as /CVCV:C/, they too will undergo that rule. We have now discovered that such stems do undergo the shortening rule, providing independent support for that rule.

Epenthesis. This reduces the unsolved part of the problem to two remaining classes of stems. In one of those, there is an alternation between presence versus absence of a vowel, and in the second group there is an alternation in vowel length as well as an alternation in the presence versus lack of a vowel in the second syllable; this should make us suspect that the vowel shortening rule applies to the second of these sets. Concentrating on the contexts where the stem has the shape CV(:)CVC as opposed to the shape CVCC, we notice that CV(:)CVC appears before consonant-initial suffixes and CVCC appears before vowel initial suffixes. We do not know at this point whether the second vowel is underlyingly part of the stem and is deleted in one context, or whether the vowel is inserted in a different context. Therefore, we will consider both possibilities.

First suppose that the vowel is not part of the underlying representation of the stem. In that case, we assume the following representations

(8)	*underlying*	ʔilk-hin	ʔilk-k'a	ʔilk-al	ʔilk-it
	surface	ʔilik-hin	ʔilik-k'a	ʔilk-al	ʔilk-it
	underlying	ṣa:lk'-hin	ṣa:lk'-k'a	ṣa:lk'-al	ṣa:lk'-it
	surface	ṣa:lik'-hin	ṣa:lik'-k'a	ṣalk'-al	ṣalk'-it

Focusing on the hypothesized underlying representations where a vowel might be inserted, we notice that a vowel appears just in case the underlying representation has a sequence of three consonants. Looking at all of the data, we notice that there are no surface sequences of three or more consonants, making such an epenthesis approach plausible.

In order for an epenthesis solution to work, the actual quality of the inserted vowel must be completely predictable. If we were to discover that the quality of the second vowel is unpredictable, then it would necessarily be part of the underlying representation since unpredictble information must be in the underlying form. The vowel which appears in the second syllable of these verbs is always a

high vowel, and it is round just in case the preceding vowel is high and round. In other words, the vowel in question is a high vowel whose backness and roundness is predictable, given the rule of vowel harmony, and thus the vowel is fully predictable. Taking into consideration the harmony rule, we can assume that the second vowel is simply *i*. It is then possible to account for these examples by applying the following rule of epenthesis.

(9) $\varnothing \rightarrow \underset{[+hi]}{V} \;/\; C\_\_CC$

Given this epenthesis rule, the underlying form of the CVCiC ~ CVCC stems would be /CVCC/ and the underlying form of the CV:CiC ~ CVCC stems would be /CV:CC/. For /CVCC/ stems like /ʔilk/, epenthesis (and vowel harmony if the first vowel is a high round vowel) applies to underlying /CVCC+CV(C)/ to give surface [CVCiC+CV(C)], and the variant CVCC found before VC suffixes directly reflects the underlying form, with respect to the presence of a vowel between the second and third consonants.

For /CV:CC/ stems like /şa:lk'/, epenthesis will also apply to underlying /CV:CC+CV(C)/ giving the surface form [CV:CiC+CV(C)]. When a VC suffix is added to such stems, there is no vowel epenthesis, but we do find shortening of the underlyingly long vowel which stands before a consonant cluster. Given the rules of vowel harmony, epenthesis and vowel shortening, combined with our analyses of underlying representations, all aspects of the data in (1) are accounted for: we conclude that epenthesis is a *possible* account of these alternations.

While the preceding analysis has assumed a rule of epenthesis based on underlying representations of the form /CVCC/ and /CV:CC/, we should explore the competing hypothesis that the vowel found in these stems is not inserted, but is part of the underlying representation. Under that hypothesis, underlying representations of the relevant stems would be the following.

(10) paʔit, ʔilik, logiw, ʔugun, lihim, ʔayiy, t'oyix, luk'ul
so:nil, ʔa:mil, mo:yin, şa:lik'

Presuming that these are the underlying stems, a rule of vowel deletion is required to explain the discrepancy between surface and underlying forms, which can be seen in (11).

(11)	*underlying*	luk'ul-hun	luk'ul-k'a	luk'ul-al	luk'ul-ut
	surface	luk'ul-hun	luk'ul-k'a	luk'l-al	luk'l-ut
	underlying	so:nil-hin	so:nil-k'a	so:nil-ol	so:nil-it
	surface	so:nil-hin	so:nil-k'a	sonl-ol	sonl-it

In forms which involve an alternation between a vowel and ∅, the context for vowel deletion would initially appear to be in an open syllable. This statement would lead to too general a rule, since there are many vowels in open syllables, viz. *x**a**tal, k'**o**ʔit, d**o:**sit, p'**a**xathin* and *p'**a**x**a:**tal* among others. In some of these cases, deletion of a vowel would lead to a word-initial consonant cluster, i.e. we would predict **xtal, *k'ʔit, *dsit, *p'xathin* and **p'x**a:**tal*, and it will be noticed that there are no word-initial clusters of consonants. If we are to have vowel deletion, the rule must be restricted from creating such clusters, and one way to enforce that requirement is to require the target of deletion to be preceded by the sequence VC. Thus, we might hypothesize the following syncope rule, one found in many languages.

(12) V → ∅ / VC ___CV

This rule still makes incorrect predictions, since in fact there are vowels in the context VC___CV, as shown by forms such as *p'axa:tal, ʔopo:tit*, which according to (12) should be deleted. Since all such examples involve long vowels, it is a simple matter to restrict the assumed deletion rule to short vowels.

(13) V → ∅ / VC ___CV
[-long]

With this rule of vowel syncope, the problem of vowel ~ ∅ alternations can also be accounted for. The remaining details of the analysis are exactly the same as they are under the assumption that there is a rule of vowel insertion.

1.4. Evaluating alternatives

In terms of simply generating the data, both the syncope and epenthesis analyses work. The question then becomes, is there a reason to chose one of these hypotheses over the other? It is entirely possible that we will not be able to come up with any compelling reasons for selecting one analysis over the other, in which case we must simply accept the fact that there are two equally plausible ways to account for the facts. As far as the simplicity, naturalness and generality of the two analyses is concerned, neither theory is superior to the other. Processes inserting vowels to break up CCC clusters are very common, as are rules of syncope which delete short vowels in the context VC___CV.[1]

We should also consider the factual predictions of the two analyses. The epenthesis analysis predicts that there should be no CCC sequences in the lan-

[1] By sheer counting of symbols, the epenthesis rule might be slightly superior since it only requires reference to five entities and syncope requires reference to seven entities. Such literal symbol counting, practiced in the early era of generative phonology, is misguided.

guage, and this appears to be correct. On the other hand, the syncope analysis predicts that there should be no short vowels in the context VC___CV, which also appears to be correct. Interestingly, neither account actually makes the prediction of the competing analysis — so, the epenthesis analysis does not preclude the existence of short vowels in the VC__CV context, and the syncope analysis does not preclude the existence of CCC sequences. If it turns out that there *are* CCC sequences in the language, the epenthesis solution will probably have to be rejected; whereas is there *are* VCVCV sequences in the language, the syncope analysis will probably have to be rejected. This would motivate further research into the language, to determine if one of these analyses makes a bad prediction.

A related issue to consider is the question of 'coincidence', in terms of assumed underlying representations. In lieu of a specific rule which restricts the occurrence of phonemes in some environment, we expect phonemes to combine without any constraints. Clearly there must be some constraints on underlying representations in Yawelmani, since for example we do not find underlying representations such as /ioate/ with sequences of vowels. In this case, there is no motivation from phonological alternations to suspect that there might be underlying forms such as /ioate/. As far as logical possibilities in underlying forms are concerned for the issue at hand — epenthesis versus deletion — both analyses result in systematic gaps in the logically possible underlying forms. Under the epenthesis analysis, there are apparently no stems of the underlying form /CVCVC/, although there are stems of the form /CVCV:C/. Under the syncope analysis, we notice that all short second-syllable vowels in disyllabic stems are in fact /i/ (surface [u] in some cases, in accordance with vowel harmony).

At this point, it is impossible to give strong arguments in favor of one analysis over another, so we accept this indeterminacy for now. The fundamental point is that each analysis implies a set of predictions about possible and impossible forms in the language, and these predictions need to be tested against the available data. In this case, we have not been able to determine that one theory is clearly superior to the other. The main research problem which we face is that the corpus of data from Yawelmani available to us at this point is restricted, so we cannot know whether generalizations which we extract about the language based on this particular corpus are representative of the language as a whole. Even if we had access to a reference grammar for the language, there is some chance that our empirical generalizations based on the data from that grammar do not hold for the whole language, if the author of the grammar is not be aware of all examples.

2. Kihehe

The following data illustrate phonological processes of Kihehe. Each noun is in one of 15 numbered 'noun classes', like 'genders' in French or German. The class of a noun is marked by a prefix. The goal is to determine the underlying form of stems and prefixes, and explain the processes at work in these data.

2.1. The data

Here are the relevant data from nouns.

(14)

Class 1			
mutesi	‘trapper’	mulagusi	‘sorcerer’
mutelesi	‘cook’	mufwiimi	‘cook’
mudesi	‘liar’	muñwi	‘drinker’
mwiimbi	‘singer’	mweendi	‘one who likes people’
mwaasi	‘builder’	moogofi	‘one who is afraid’
moofusi	‘one who washes’	muuci	‘one who comes’
Class 2			
vatesi	‘trappers’	valagusi	‘sorcerers’
vatelesi	‘cooks’	vafwiimi	‘cooks’
vadesi	‘liars’	vañwi	‘drinkers’
viimbi	‘singers’	veendi	‘ones who like people’
vaasi	‘builders’	woogofi	‘ones who are afraid’
woofusi	‘one who washes’	wuuci	‘one who comes’
Class 3			
muhoomi	‘cow hump’	muhogo	‘cassava’
mufuniko	‘cover’	muvili	‘body’
mwiina	‘hole’	mwiigiigi	‘shadow’
mweenda	‘cloth’	mooto	‘fire’
muuñu	‘salt’		
Class 4			
mihoomi	‘cow humps’	mihogo	‘cassavas’
mifuniko	‘covers’	mivili	‘bodys’
miina	‘holes’	miigiigi	‘shadows’
myeenda	‘cloths’	myooto	‘fires’
myuuñu	‘salts’		
Class 6			
mavafi	‘hairy caterpillars’	masaasi	‘bullets’
maboga	‘pumpkins’	mayayi	‘legs’
miino	‘teeth’	miiho	‘eyes’
Class 7			
kikoongo	‘wound’	kibiki	‘tree stump’
kigidi	‘waist’	kingaamba	‘sweet potato’
kisogo	‘back of head’	čuula	‘frog’

čuunga	‘wet lowland’	čaanga	‘grave’
kifiniko	‘dinky cover’	kivili	‘dinky body’
kihoomi	‘dinky cow hump’	kivafi	‘dinky hairy caterpillar’
čooto	‘dinky fire’	čeenda	‘dinky cloth’
čuuñu	‘dinky salt’	kiiho	‘dinky eye’
kiina	‘dinky hole’	kiigiigi	‘dinky shadow’

Class 8

fikoongo	‘wounds’	fibiki	‘tree stumps’
figidi	‘waists’	fingaamba	‘sweet potatos’
fisogo	‘backs of head’	fyuula	‘frogs’
fyuunga	‘wet lowlands’	fyaanga	‘graves’
fifiniko	‘dinky covers’	fivili	‘dinky bodys’
fihoomi	‘dinky cow humps’	fivafi	‘dinky hairy caterpillars’
fyooto	‘dinky fires’	fyeenda	‘dinky cloths’
fyuuñu	‘dinky salts’	fiiho	‘dinky eyes’
fiina	‘dinky holes’	fiigiigi	‘dinky shadows’

Class 11

luteefu	‘reed mat’	lupava	‘stirring stick’
lutego	‘trap’	ludali	‘power
luhaanga	‘sand’	lwiimbo	‘song’
lweendo	‘loving’	lwaaniko	‘dry stuff’
lwiifwi	‘chameleon’		

Class 12

kateefu	‘small mat’	kakoongo	‘small wound’
kadesi	‘small liar’	kahogo	‘small cassava’
kafuniko	‘small cover’	kangaamba	‘small sweet potato’
kaasi	‘small builder’	kiimbi	‘small singer’
kaanga	‘small grave’	kooto	‘small file’
kuula	‘small frog’	kuunga	‘small wet lowland’

Class 13

tuteefu	‘small mats’	tukoongo	‘small wounds’
tudesi	‘small liars’	tuhogo	‘small cassavas’
tufuniko	‘small covers’	tungaamba	‘small sweet potatos’
twaasi	‘small builders’	twiimbi	‘small singers’
twaanga	‘small graves’	tooto	‘small files’
tuula	‘small frogs’	tuunga	‘small wet lowlands’

Class 14

wuvaso	'sleeping place'	wulime	'cultivating'
wubi	'evil'	wugiimbi	'beer'
wugali	'porridge'	wutiitu	'blackness'
weelu	'whiteness'	wuumi	'life'
woogofu	'fear'	wiiyooga	'mushroom'
waangufu	'speed'		

2.2. Morphological analysis

As always, a preliminary morphological analysis is the first step in solving a phonology problem. Each noun has some prefix that marks noun class, followed by a stem. We also see, comparing nouns in various classes, that the same stems can appear in different classes, so for example class 3 *mu-hoomi* 'cow hump' is clearly related to class 4 *mi-hoomi* 'cow humps' — singulars and plurals are marked by changes in class; class 11 *lu-teefu* 'reed mat' is clearly related to *ka-teefu* 'small mat' and *tu-teefu* 'small mats'. The class prefixes have a number of phonetic manifestations, so we find *mu-*, *mw-* and *m-* for classes 1 and 3, *va*, *v-* and *w-* for class 2, *mi-*, *my-* and *m-* for class 4, *ma-* and *m-* for cl. 6, *ki-* and *č-* for class 7, *fi-* and *fy-* for class 8, *lu-* and *lw-* for class 11, *ka-* and *k-* for class 12, *tu-* and *tw-* for class 13, and *wu-*, *w-* for class 14.

2.3. Phonological alternations

Noun stems fall in two groups in terms of phonological processes: those which begin with a consonant, and those beginning with a vowel. Examples of stems which begin with a consonant would include *-tesi* (cf. *mu-tesi, va-tesi*) and *-lagusi* (cf. *mu-lagusi, va-lagusi*); examples of stems which begin with vowels would include *-iimbi* (cf. *mw-iimbi*, *v-iimbi*) and *-eendi* (*mw-eendi, v-eendi*). The best phonological information about the nature of the prefix is available from its form before a consonant, so our working hypothesis is that the underlying form of the noun prefix is that found before a consonant — it preserves more information.

As we try to understand the phonological changes found with vowel-initial stems, it is helpful to look for a general unity behind these changes. One important generalization about the language, judging from the data, is that there are no vowel sequences in the language (what seem to be sequences such as *ii*, *ee* are not sequences, but are the orthographic representation of single long vowel segments). Given the assumption that the prefixes for classes 1 and 2 are respectively /mu/ and /va/, the expected underlying forms of 'singer' and 'singers' would be /mu-iimbi/ and /va-iimbi/. These differ from the surface forms [mw-iimbi] and [v-iimbi]: in the case of /mu-iimbi/, underlying /u/ has become [w], and in the case of underlying /va-iimbi/, underlying [a] has been deleted. In both cases, the end result is that an underlying cluster of vowels has been eliminated.

Glide formation vs. vowel deletion. Now we should ask, why is a vowel deleted in one case but turned into a glide in another case? The answer lies in the nature of the prefix vowel. The vowel /u/ becomes the glide [w], and the only difference between *u* and *w* is that the former is syllabic (a vowel) where the latter is nonsyllabic. The low vowel /a/, on the other hand, does not have a corresponding glide in this language (or in any language). In other words, a rule of glide-formation simply could not apply to /a/ and result in a segment of the language.

To make progress in solving the problem, we need to advance hypotheses and test them against the data. We therefore assume the following rules of glide formation and vowel deletion.

(15) $\underset{[+hi]}{V} \rightarrow$ [-syll] / __ V

(16) V → ∅ / __ V

By ordering (16) after (15), we can make (16) very general, since (15) will have already eliminated other vowel sequences. At this point, we can simply go through the data from top to bottom, seeing whether we are able to account for the examples with no further rules — or, we may find that other rules become necessary.

For nouns in class 1, the examples *mw-iimbi*, *mw-eendi* and *mw-aasi* are straightforward, deriving from /mu-iimbi/, /mu-eendi/ and /mu-aasi/. The forms *m-oogofi*, *m-oofusi* and *m-uuci* presumably derive from /mu-oogofi/ and /mu-oofusi/ and /mu-uuci/. The vowel /u/ has been deleted, which seems to run counter to our hypothesis that high vowels become glides before vowels. It is possible that there is another rule that deletes /u/ before a round vowel.

(17) $u \rightarrow \varnothing \,/\, \_\_\_ \underset{[+round]}{V}$

We could consider letting the glide formation rule apply and then explain the difference /mu-aasi/ → *mw-aasi* vs. /mu-oofusi/ → *m-oofusi* by subjecting derived *mw-oofusi* to a rule deleting *w* before a round vowel.

(18) w → ∅ / ___ [+round]

v-rounding. Now we consider examples from class 2. Again, in stems beginning with a vowel, we can easily explain *v-iimbi, v-eendi* and *v-aasi* from *va-iimbi, va-eendi* and *va-aasi*, where *a*-deletion applies. Something else seems to be happening in *w-oogofi, w-oofusi* and *w-uuci* from *va-oogofi, va-oofusi* and *va-uuci*. Application of *a*-deletion would yield *v-oogofi, v-oofusi* and *v-uuci*, which differ from the surface forms only in the replacement of *v* by *w*. Since this process takes place be-

fore a round vowel, we conjecture that there may be an assimilation rule such as the following.

(19) v → w / ___ [+round]

If there is such a rule in the language, it would eliminate any sequences *vu*, *vo*: and the data contains no such sequences. There is still a problem to address, that *w*-deletion (18) should apply to *woogofi* but it does not — the surface form is not *[oogofi]. Two explanations come to mind. One is that *v*-rounding is ordered after *w*-deletion, so at the stage where *w*-deletion would apply, this word has the shape *voogofi* and not *woogofi* (so *w*-deletion cannot apply). The other is that (18) needs to be revised, so that it only deletes a post-consonantal *w* before a round vowel.

(20) w → ∅ / C ___ [+round]

Our decision-making criteria are not stringent enough that we can definitively chose between these solutions, so we will leave this question open for the time.

Moving to other classes, the nouns in class 3 present no problems. Glide formation applies to this prefix, so /mu-iina/ → [mw-iina], and before a round vowel derived *w* deletes, so /mu-ooto/ → *mw-ooto* which then becomes [m-ooto].

Front vowels and glides. The nouns in class 4 generally conform to the predictions of our analysis. Note in particular that underlying /mi-uuñu/ and /mi-ooto/ undergo glide formation before a round vowel. Such examples show that it was correct to state glide formation rule in a more general way, so that all high vowels (and not just /u/) become glides before any vowel (not just non-round vowels).

We cannot yet fully explain what happens with noun stems beginning with the vowel *i*, as in *m-iina, m-iigiigi*. Given /mi-iina/, /mi-iigiigi/, we predict surface **my-iina, *my-iigiigi*. This is reminiscent of the problem of /mu-oogofi/ and /mu-uuci/ and we might want to generalize the rule deleting a glide, to include deleting a front glide before a front vowel (analogous to deleting a round glide before a round vowel). What prevents us from doing this is that while *w* deletes before both *u* and *o*, *y* only deletes before *i* and not *e*, as we can see from *my-eenda*. It might be more elegant or symmetrical for round glides to delete before round vowels of any height *and* front glides to delete before front vowels of any height, but the facts say otherwise: a front glide only deletes before a front *high* vowel.

(21) $\begin{bmatrix} +\text{hi} \\ -\text{back} \\ -\text{syl} \end{bmatrix} \rightarrow \varnothing \,/\, \_\_\_ \begin{bmatrix} +\text{hi} \\ -\text{back} \end{bmatrix}$

Checking other classes: discovering a palatalization rule. The class 6 prefix *ma*- presents no surprises at all: it appears as *ma*- before a consonant, and its vowel deletes before another vowel, as in *m-iino* from *ma-iino*. The class 7 prefix, on the other hand, is more complex. Before a consonant it appears as *ki*-, and also appears as *k*(*i*)- before *i*. Before other vowels, it appears as *č*, as in *č-uula, č-aanga, č-ooto* and *č-eenda*. Again, we continue the procedure of comparing the underlying and predicted surface forms (predicted by mechanically applying the rules which we have already postulated to the underlying forms we have committed ourselves to), to see exactly what governs this discrepancy. From underlying *ki-uula, ki-aanga, ki-ooto* and *ki-eenda* we would expect *ky-uula, ky-aanga, ky-ooto* and *ky-eenda*, given glide formation. The discrepancy lies in the fact that the predicted sequence *ky* has been fused into *č*, a process of palatalization found in many languages. Since *ky* is nowhere found in the data, we can confidently posit the following rule.

(22) ky → č

Since /ki/ surfaces as [č] when attached to a vowel-initial noun stem, the question arises as to what has happened in *k-iiho, k-iina* and *k-iigiigi*. The glide formation rule should apply to /ki-iiho/, /ki-iina/ and /ki-iigiigi/ giving *ky-iiho, ky-iina* and *ky-iigiigi*, which we would expect to undergo (22). But there is a rule deleting *y* before *i*. If *y* is deleted by that rule, it could not condition the change of *k* to *č*, so all that is required is the ordering statement that *y*-deletion precedes palatalization (22). Thus /ki-iina/ becomes *ky-iina* by glide formation, and before the palatalization rule can apply, *y*-deletion rule (21) deletes the glide that is crucial for (22).

Deciding on the form of w-deletion; degemination. At this point, we can quickly check the examples in classes 8, 11, 12 and 13 and verify that our analysis explains all of these forms as well. The final set of examples are those in class 14, which has the prefix /wu/. This prefix raises a question in terms of our analysis: why do we have the sequence [wu], which is eliminated by a rule elsewhere? One explanation is the statement of the rule itself: if (20) is the correct rule, then this *w* could not delete because it is not preceded by a consonant. The other possibility is that [wu] actually comes from /vu/ by applying *v*-rounding (19), which we assumed applies after *w*-deletion. While both explanations could be right possible, the analysis where [wu] is underlying /vu/ has the disadvantage of being rather abstract, in positing an underlying segment in the prefix which never appears as such. This issue was presaged in chapter 4 and is discussed in more detail in chapter 10, but for the moment we will simply say that given a choice between a concrete analysis where the underlying form of a morpheme is composed only of segments which actually appear as such in some surface manifestation of the morpheme, and an abstract form with a segment that never appears on the surface, the concrete analysis is preferable to the abstract one, all other things being comparable. On that basis, we decide that the underlying for of the class 14 prefix is /wu/, which means

that the proper explanation for failure of *w*-deletion lies in the statement of *w*-deletion itself, as (20).

Still analysing this class of nouns, we now focus on examples where the prefix precedes a vowel-initial stem, e.g. *w-eelu, w-uumi, w-oogofu, w-iiyooga* and *w-aangufu* from underlying /wu-eelu/, /wu-uumi/, /wu-oogofu/, /wu-iiyooga/ and /wu-aangufu/. Applying glide formation would give the surface forms **ww-eelu,* **ww-uumi,* **ww-oogofu,* **ww-iiyooga* and **ww-aangufu*, which differ from the surface form in a simple way, that they have a geminate *w* where the actual form has only a single *w* (in fact, there do not seem to be any geminate consonants in the language), which allows us to posit the following degemination rule.

(23) $C_iC_i \rightarrow C_i$

2.4. Extending the data

Verbs are subject to these same rules, as some additional data will show, and an analysis of verbs will provide additional support for aspects of this analysis. Kihehe is a tone language, and while we have not been concerned with accounting for tone (and have not marked tones), in the following data, tones are marked, and can be predicted by rule. In analyzing these data, we want to account for the placement of the High tone (H), which is marked with an acute accent.

(24)

V	**V for**	**V for each**	**make V**
kúkama	kúkamíla	kúkamilána	kúkamyá
kúsana	kúsaníla	kúsanilána	kúsanyá
kútova	kútovéla	kútovelána	kútovyá
kúlava	kúlavíla	kúlavilána	kúlavyá
kúfwiíma	kúfwiimíla	kúfwiimilána	kúfwiimyá
kúkalaánga	kúkalaangíla	kúkalaangilána	kúkalaangyá
kúkaláva	kúkalavíla	kúkalavilána	kúkalavyá
kwéenda	kwéendéla	kwéendelána	kwéendyá
kwíimba	kwíimbíla	kwíimbilána	kwíimbyá
kóogópa	kóogopéla	kóogopelána	kóogopyá

be V'd	**V us**	**V them**	**meaning**
kúkamwá	kútukáma	kúvakáma	milk
kúsanwá	kútusána	kúvasána	comb
kútowá	kútutóva	kúvatóva	beat
kúlawá	kútuláva	kúvaláva	look at
kúfwiimwá	kútufwiíma	kúvafwiíma	hunt
kúkalaangwá	kútukalaánga	kúvakalaánga	fry
kúkalawá	—	—	take bath
kwéendwá	kútweénda	kúveénda	love

kwíimbwá	kútwiímba	kúviímba	sing
kóogopwá	kútoogópa	kúwoogópa	fear

The morphology. These data indicate that all verbs begin with *kú* or something derivable from /kú/ by the rules already motivated, thus we assume that *kú-* is an inflectional prefix. In addition, all verbs end with the vowel *a*, which is probably a morpheme since it is unlikely that every root would end in the same vowel. The stem 'milk' is probably *-kam-*. Various grammatical relations are expressed by suffixes standing between the stem and the suffix *-a*, such as *-il-* 'for', *-an-* 'each other', *-y-* 'make', *-w-* passive: the objects 'us' and 'them' are marked by the prefixes *-tu-* and *-va-* between the prefix *kú-* and the verb stem.

Phonological rules. Looking at the last three roots, which are vowel-initial, the prefixes *kú-*, *tu-* and *va-* are subject to the rules motivated on the basis of nouns, where /u/ becomes [w] before a vowel, but deletes after a consonant and before a round vowel (so, /ku-oogopa/ → *kwoogopa* → [koogopa]); the sequence *vo* becomes *wo* (/ku-va-oogopa/ → *kuvoogopa* → [kuwoogopa]). The change of /v/ to *w* is also seen in examples such as *kútowá* and *kúlawá*, coming (apparently) from /ku-tov-w-a/ and /ku-lav-w-a/. The rule of *v*-rounding would derive *kútowwá* and *kúlawwá*, and the actual phonetic forms can be accounted for based on that intermediate form by degemination.

One additional segmental process of vowel harmony is motivated by the above examples. The benefactive suffix retains its underlying high vowel in forms such as *kúkam-íl-a, kúsan-íl-a* and *kúfwiim-íl-a*, but that vowel assimilates in height to a preceding mid vowel in examples such as *kútov-él-a, kwéend-él-a* and *kóogop-él-a*. This motivates the following rule:

(25) $V \rightarrow [-hi] \; / \; \begin{matrix} V \\ \begin{bmatrix} -hi \\ -low \end{bmatrix} \end{matrix} \; C_0 \; \_\_\_$

Regarding tone, most examples have a H tone on the second-to-last vowel of the word (this may be the second part of a long vowel in the penultimate syllable, or the only vowel of a short penultimate syllable), which can be accounted for by the following rule.

(26) $V \rightarrow [+H] \; / \; \_\_ \; C_0 \; V\#$

In some verbs, this H is missing — cf. *kúkama, kúsana, kútova*. Applying this tone assignment rule to these forms would result in outputs such as **kúkáma, *kúsána, *kútóva*, with H tones on adjacent vowels. Since our examples contain no cases of consecutive toned vowels, we may assume a rule along the following lines.

(27) $V \rightarrow [-H] \; / \; \underset{[+H]}{V} \; C_0 \; \_\_\_$

What about the columns with the suffixes -*y*- 'make' and -*w*- 'passive', which have word-final H, not penult H ? We expect **kúkalaángwa*. But if these two suffixes are underlyingly *i* and *u*, then the underlying form of *kúkalaangwá* would be /kú-kalaang-u-a/. H tone would be assigned to the penultimate vowel under that assumption, giving *kúkalaangúa*. However, we already know that there is a rule of glide formation which would turn *u* and *i* into *w* and *y* before vowels, a rule which has obviously applied in these forms. Since only syllabic elements can bear tones, the tone on the penultimate vowel apparently shifts to the final syllable, where it can be pronounced.

Such tone shift, where the tone of a vowel shifts to another vowel when the original vowel deletes or desyllabifies is common in tone languages and is discussed in the last chapter

3. Icelandic

Our next example is alternations in noun inflection in Modern Icelandic.

3.1. The data

The relevant data are in (28). The task is to provide a unique underlying representation for each stem and case suffix, state what phonological rules are required to account for these data, and indicate what order they apply in, when the ordering of rules matters.

(28)

hestür	hattür	heimür	gröütür	skougür	*nom. sg*
hest	hatt	heim	gröüt	skoug	*acc. sg.*
hesti	hatti	heimi	gröüti	skougi	*dat. sg.*
hests	hatts	heims	gröüts	skougs	*gen. sg.*
hestar	hattar	heimar	gröütar	skougar	*nom. pl.*
hesta	hatta	heima	gröüta	skouga	*acc. pl.*
hestüm	höttüm	heimüm	gröütüm	skougüm	*dat. pl*
'horse'	'hat'	'home'	'porridge'	'forest'	
garðür	laiknir	hirðir	himinn	morgünn	*nom. sg.*
garð	laikni	hirði	himin	morgün	*acc. sg.*
garði	laikni	hirði	himni	morgni	*dat. sg.*
garðs	laiknis	hirðis	himins	morgüns	*gen. sg.*
garðar	laiknar	hirðar	himnar	morgnar	*nom. pl.*
garða	laikna	hirða	himna	morgna	*acc. pl.*
görðüm	laiknüm	hirðüm	himnüm	morgnüm	*dat. pl.*
'garden'	'doctor'	'herd'	'heaven'	'morning'	

stoull	magaull	yökül̈l	θümall	mour	*nom. sg.*
stoul	magaul	yökül	θümal	mou	*acc. sg.*
stouli	magauli	yökli	θümli	mou	*dat. sg.*
stouls	magauls	yökül̈s	θümals	mous	*gen. sg.*
stoular	magaular	yöklar	θümlar	mouar	*nom. pl.*
stoula	magaula	yökla	θümla	moua	*acc. pl.*
stoulüm	magaulüm	yöklüm	θümlüm	mouüm	*dat. pl.*
'chair'	'flank'	'glacier'	'thumb'	'peat'	

akür	hamar	hver	galdür	byour	*nom. sg.*
akür	hamar	hver	galdür	byour	*acc. sg.*
akri	hamri	hver	galdri	byour	*dat. sg.*
akürs	hamars	hvers	galdurs	byours	*gen. sg.*
akrar	hamrar	hverar	galdrar	byourar	*nom. pl.*
akra	hamra	hvera	galdra	byoura	*acc. pl.*
ökrüm	hömrüm	hverüm	göldrüm	byourüm	*dat. pl.*
'field'	'hammer'	'geyser'	'magic'	'beer'	

3.2. Morphological analysis

It is not immediately clear what are appropriate underlying representations for some case suffixes. It would appear that the nom. sg. ending is something like -*ür* or maybe -*ir*, although sometimes you just find lengthening of a stem final consonant. We start by assuming that the acc. sg. has no case suffix, the dat. sg. is -*i*, the gen. sg. is -*s*, the nom. pl. is -*ar*, the acc. pl. is -*a* and the dat. pl. is -*üm*, since in almost all stems, that is how these suffixes are actually manifested. It would similarly not be unreasonable to assume that the acc. sg. form is a close approximation of the underlying form of the stem.

3.3. Phonological alternations

On the basis of these assumptions about underlying forms, we can identify some phonological alternations which need to be explained. First and foremost, we need to explain the variation in the nom. sg. Second, we need to explain the alternation between [a] and [ö] in examples such as [hatta] ~ [höttüm]. Third, there is a vowel ~ ∅ alternation as in [himin] ~ [himna] and [morgün] ~ [morgna]. Fourth, the dat. sg. form generally appears as [i], but in some cases does not surface. We will try to solve one of these problems, selecting at random, since at this point we have no reason to think that finding a solution to one of these problems is dependent on finding a solution to any other of these problems.

The vowel of the nominative singular. We will begin with the problem of the nominative singular. The first step in taming this problem is to state exactly what

the problem is: there are many apparent realizations of this suffix, depending on the noun stem to which it is attached, we find *-ür*, *-ir*, *-r*, -∅ , *-l* and *-n*. Constructing this list of surface realizations alone is enough to allow us to make an initial guess about the underlying form, which is that the nom. sg. is -(V)*r*, since half of the variants of this affix actually contain *-r* (of course, this assumption could be wrong, since numerical counts are not arguments for underlying forms, only suggestions, but again we need to start somewhere). The next step is to extract generalizations about the contexts where each variant is used. We would start by listing the stems themselves, noting that we have *-ur* with /hest/, /hatt/, /gröüt/, /heim/, /garð/ and /skoug/, *-r* with /mou/, /laikni/ and /hirði/, ∅ with /akür/, /hamar/, /hver/ and /galdür/, *-l* with /stoul/, /magaul/ and /yökül/, and *-n* with /himin/ and /morgün/. At this point, generalizations about the underlying form become easier to see: we find [l] after /l/, [n] after /n/, ∅ after /r/, [r] after a vowel and [ür] after any other consonant. We can conclude that the most likely underlying forms for this suffix are /ür/ and /r/.

You may wonder, why assume that *garðür* illustrates the variant *-ur* and *galdür* does not? We assumed that the. acc. sg. best reflects the underlying form, and since [ür] is present in acc. sg. *galdür* but not *garð*, [ür] must be part of the stem in *galdür* and not in *garðür*.

Having identified the nature of the conditioning environment and armed with two hypotheses about the underlying form, it is time to transform this information into specific rules. Since underlying representations and rules go hand in hand, we need to determine whether one of the assumed underlying representations for the suffix results in more plausible rules. Let of consider the entailments of these underlying forms in terms of the rules that they commit us to.

(29) **Hypothesis: /ür/**

No change:

hest-ür → hestür, hatt-ür → hattür, skoug-ür → skougür, heim-ür → heimür, garð-ür → garðür, gröüt-ür → gröütür

Deletion of a vowel

mou-ür → mour, laikni-ür → laiknir, hirði-ür → hirðir

Deletion of a vowel and r

akür-ür → akür, hver-ür → hver, byour-ür → byour, galdür-ür → galdür, hamar-ür → hamar

Deletion of a vowel and assimilation

stoul-ür → stoull, yökul-ür → yökül-ür, θümal-ür → θümall, himin-ür → himinn, magaul-ür → magaull, morgün-ür → morgünn

Hypothesis: /r/

Insertion of a vowel

hest-r → hestür, hatt-r → hattür, skoug-r → skougür, heim-r → heimür, garð-r → garðür, gröüt-r → gröütür

No change

mou-r → mour, laikni-r → laiknir, hirði-r → hirðir

Deletion of r
akür-r → akür, hver-r → hver, byour-r → byour, galdür-r → galdür, hamar-r → hamar
Assimilation
stoul-r → stoull, yökül-r → yökül-ür, θümal-r → θümall, himin-r → himinn, magaul-r → magaull, morgün-r → morgünn

If the suffix is underlyingly /ür/, a deletion rule is required to eliminate *ü* from this suffix when it is preceded by one of /r,l,n/.

(30) $$\begin{bmatrix} +\text{syl} \\ +\text{hi} \\ +\text{rd} \end{bmatrix} \rightarrow \varnothing \,/\, \text{V} \begin{bmatrix} +\text{coronal} \\ +\text{sonorant} \end{bmatrix} \_\_\ \text{r}\ \#$$

Applying this rule to underlying *himinür, stoulür, hverür* would yield forms such as *himinr, stoulr, hverr*, and these outputs would be subject to other rules.

In addition, we would require a rule to delete the vowel from the suffix when the preceding stem ends in a vowel. This rule would allow us to account for forms such as *mour, laiknir*, and *hirðir*, from assumed *mou-ür, laikni-ür*, and *hirði-ür*. Deletion of a vowel after another vowel is not implausible, so we might postulate the following rule.

(31) $\text{V} \rightarrow \varnothing \,/\, \text{V}\ \_\_$

However, this is too general, since *u* can be preceded by other vowels — cf. *mour, skougür, magaull*. This particular statement of the rule makes a prediction that certain kinds of phonetic sequences should not occur, and that prediction is wrong. Our rule went wrong in that it does not distinguish supposed vowel combinations which would be created by concatenation of morphemes (these sequences do undergo reduction) from diphthongs which are contained wholely within a single morpheme (which do not undergo reduction). We could attempt to overcome this shortcoming by specifically requiring that the two vowels be in separate morphemes, as indicated in the following rule.

(32) $\text{V} \rightarrow \varnothing \,/\, \text{V} + \_\_$

Even this restriction is insufficient, since it does not explain why the supposed suffix vowel in /laikni-ür/ and /hirði-ür/ deletes, but in the nom. pl, acc. pl and dat pl., the vowels of the suffix -*ar*, -*a* and -*üm* are not deleted (cf. *laiknar, hirðar, laikna, hirða, laiknüm, hirðüm*): rather, the vowel of the stem deletes. Particularly troublesome for the hypothesis that the nom. sg suffix is /ür/ is the fact

that the dative plural suffix -*üm* acts so different. These problems could be remedied by requiring the vowel which deletes to be *ü*, and by deleting *ü* only before *r*.

(33) ü → ∅ / V + __r

In lieu of a competing hypothesis, it is difficult to know whether this rule is right, but given the very specific information which has to be included in this rule to make it work, you should be suspicious of the rule.

At this point, we are so thoroughly suspicious of the hypothesis of underlying /ür/ that we have a reason to look for an alternative hypothesis, to see if different assumptions about underlying forms simplify the description. The competing hypothesis that the suffix is /r/ requires a rule to insert *ü* before *r* just in case a consonant precedes.

(34) $\varnothing \rightarrow$ ü / C __ r# or $\varnothing \rightarrow \begin{bmatrix} +\text{syl} \\ +\text{hi} \\ +\text{rd} \\ -\text{bk} \end{bmatrix} / \text{ C } \_\_ \begin{bmatrix} -\text{syl} \\ +\text{son} \end{bmatrix} \#$

This rule does not apply to /morgün-r/, since we have [morgünn] and not *[morgünür], but that fact does not have to be directly stated in the epenthesis rule. The explanation is straightforward: another rule eliminates underlying /nr#/, giving [nn] instead: rule ordering matters. Given the generality of the epenthesis rule versus the highly specific nature of the *ü*-deletion rule, we reject the *ü*-deletion hypothesis, therefore the underlying form of the nominative singular must be /r/.

Vowel deletion. Now that we understand that the nom. sg. suffix is /r/ and *ü* which appears before it is actually epenthetic, we turn to vowel-plus-vowel sequences. The stems *lakni, hirði* and *mou* end in vowels or diphthongs, and when a vowel initial suffix comes after the stem, a vowel is deleted. Examples are repeated below, this time including in parentheses the underlying vowel which is deleted.

(35)	laikn(i)-i	hirð(i)-i	mou-(i)	*dat. sg.*
	laikn(i)-ar	hirð(i)-ar	mou-ar	*nom. pl.*
	laikn(i)-a	hirð(i)-a	mou-a	*acc. pl.*
	laikn(i)-üm	hirð(i)-üm	mou-üm	*dat. pl*
	'doctor'	'herd'	'peat'	

The simple generalization is that the vowel *i* deletes before or after another vowel between morphemes (in an example such as [laikni] from /laikni+i/, we cannot tell which *i* is deleted). Thus we may posit the following rule.

(36) $i \rightarrow \varnothing / \begin{Bmatrix} V + \_ \\ \_ + V \end{Bmatrix}$

This can be written $i \rightarrow \varnothing$ % __+V. The symbol '%' is the mirror-image notation meaning "before or after".

Sonorant clusters with r. Two other rules are required which affect certain C+r sequences. One assimilates /r/ to a preceding /l/ or /n/. The question arises, are /l/ and /n/, to the exclusion of /r/, a natural class? The consonants /l/ and /n/ have in common the properties of being coronal sonorants, but so does /r/. The consonant /r/ is [-nasal], but so is /l/; /r/ is [-lateral], but so is /n/. Thus, it would be impossible to refer to the class of consonants /l,n/ excluding /r/. But it is not *necessary* to explicitly state the assimilation rule so that it only applies after /l,n/, since /r/ deletes after another /r/ anyhow. In other words, we need the following rule:

(37) $r \rightarrow \varnothing / r\_\_\_$

The sonorant-assimilation rule can therefore be stated generally as:[2]

(38) $r \rightarrow \begin{bmatrix} \alpha\text{lateral} \\ \beta\text{nasal} \end{bmatrix} / \begin{bmatrix} +\text{sonorant} \\ +\text{coronal} \\ \alpha\text{lateral} \\ \beta\text{nasal} \end{bmatrix} \_\_$

This rule change /lr/ into [ll], /nr/ into [nn] and vacuously changes /rr/ into [rr]: the independent process of r-deletion will still simplify the resulting sequence of *r*'s.

Syncope. The next problem which we will take on is the vowel ~ ∅ alternation found for example in [himin] ~ [himni]. Not all stems participate in this alternation, so we do find the alternation in the stems *akür, galdür, himin, hamar, morgun, yökül* and *θümal* but not *hest, hatt, heim, garð, gröüt, skoug, mou, stoul, hver, byour, magaul* (we will consider /laikni/ and /hirði/ later). A simple generalization determines which stems alternate: only single vowels outside the initial syllable are subject to the alternation. Now we must ask under what circumstances the vowel deletes. Taking /himin/ as representative, we can list the contexts:

[2] Recall the use of Greek-letter variable for formulating assimilation rules, discussed in chapter 6. This rule states that /r/ takes on the same values for lateral and nasal as found in the preceding consonant.

(39) *CVCVC stem*
himin-n (nom. sg.), himin (acc. sg.), himin-s (gen. sg.)

CVCC stem
himn-i (dat. sg.), himn-ar (nom. pl.), himn-a (acc. pl.), himn-üm (dat. pl)

In other words, there is no vowel before a vowel-initial suffix.

Having isolated the context in which a vowel is deleted, we can offer a phonological rule of vowel syncope.

(40) $\underset{[-\text{long}]}{V} \rightarrow \varnothing \,/\, VC_0 \_\_\_ CV$

ü-umlaut. This now leaves us with the problem of the alternation between [a] and [ö]. In looking for a context where this vowel change happens, we note that it takes place before the dative plural suffix *-üm*, which underlyingly has the front round vowel [ü], and thus involves an assimilation in roundness and backness.

(41) $a \rightarrow ö \,/\, \_\_ \, C_0 \, ü$

It is evident, given examples such as [hattür] from /hatt-r/, that the vowel [ü] inserted by ü-epenthesis does not trigger this rule, which can be explained by ordering the rule of round-harmony (41) before u-insertion (34).

i-deletion. The final fact to be explained is that while the dative singular suffix is *-i*, the dative singular of the stems *akür, hver, byour, galdür* is identical to the stem — the vowel *i* is missing. This can be accounted for by a rule deleting *i* after *r*.

(42) $i \rightarrow \varnothing \,/\, r \_\_ \#$

Reconsidering /akür/. We are nearly finished with our analysis of Icelandic phonology, but one area of data needs further consideration. We assumed the underlying representations of 'field' and 'magic' to be /akür/ and /galdür/, based on the fact that that is how they appear phonetically in the accusative singular, and this form has generally been a good diagnostic of the underlying representation. However, there is a problem with assuming underlying /akür/ and /galdür/, that the rule of rounding assimilation would be expected to apply in these forms, giving incorrect **ökür, *ökürs*. This problem can be resolved by modifying our assumption about the underlying form, since we already have a rule which inserts *ü* before *r* — a rule which applies after rounding assimilation (epenthetic *ü* does not trigger rounding). Therefore, we change our assumption about underlying forms, to /akr/ and /galdr/. This entails a small change in the way that we formalize the rule of epenthesis, since that rule as presently stated only inserts *ü* before *r* which is in

word final position, and yet we also want to be able to insert *ü* before *r* which stands before another consonant, in order to explain /akr-s/ → [akürs].

(43) ∅ → ü / C __ r {C,#}

Commonly, the expression {C,#} indicates syllable structure: the rule prevents Cr at the end of a syllable.

4. Modern Hebrew

The next case-study in this chapter comes from a set of alternations in the conjugation of verbs in a certain derivational class in Modern Hebrew.[3]

4.1. The data

The goal of this problem is to determine the underlying representations of the verbal prefix and the stems, as well as whatever rules are needed to account for these phonological alternations. In some cases, a related word is provided in order to clarify aspects of the underlying stem.

(44)

1 sg.	*2 sg. msc*	*3 sg. fem*	*gloss*	*related word*	*gloss*
itparnasti	itparnes	itparnesu	earn		
itparsamti	itparsem	itparsemu	become famous		
idbalbalti	idbalbel	idbalbelu	be confused		
idgalgalti	idgalgel	idgalgelu	revolve		
itħamakti	itħamek	itħamku	turn away		
itlabašti	itlabeš	itlapšu	get dressed		
idbadarti	idbader	idbadru	make fun		
idgarašti	idgareš	idgaršu	divorce		
itpalalti	itpalel	itpalelu	pray		
itxamamti	itxamem	itxamemu	warm		
itmotati	itmotet	itmotetu	quake		
itʔošašti	itʔošeš	itʔošešu	recover		
idbodati	idboded	idbodedu	seclude oneself		
istaparti	istaper	istapru	get a haircut	sapar	barber
istarakti	istarek	istarku	comb hair	ma-srek	comb
ištaparti	ištaper	ištapru	improve	šipur	improvement
itˢtalamti	itˢtalem	itˢtalmu	have photo taken	tˢalem	photographer

[3] These data are from a nonstandard dialect that has pharyngeals which were lost in the standard dialect, either being deleted (in the case of ʕ) or changed to *x* (in the case of *ħ*).

izdakanti	izdaken	izdaknu	age	zaken	old
izdarasti	izdarez	izdarzu	hurry	zariz	alert
itamamti	itamem	itamemu	feign innocence	tamim	innocent
idardarti	idarder	idarderu	decline	dirdur	rolling
itpatahti	itpateah	itpathu	develop		
idgalahti	idgaleah	idgalhu	shave		
itnatˢahti	itnatˢeah	itnatˢhu	argue		
ištagati	ištagea	ištagʔu	become mad		
itparati	itparea	itparʔu	cause disorder		
itmaleti	itmale	itmalʔu	become full		
itpaleti	itpale	itpalʔu	become surprised		
itnaseti	itnase	itnasʔu	feel superior		

4.2. Morphological analysis

Each verb has a prefix which is either /it/ or /id/, and it transparently surfaces as one of these two variants in most examples. The 1 sg. form is marked with a suffix *-ti*, 3 sg. fem. has the suffix *-u*, and the 2 sg. masc. has no suffix. The vowel in the second stem syllable is underlyingly the same for all verbs: this fact is not entirely obvious from these data but is made obvious by a more extensive analysis of the morphological structure of words in the language. An analysis of the phonological factors surrounding the second vowel will show that these surface variants can be derived from one particular underlying vowel. Derivationally related words, such as the root underlying *ištaparti* 'improve' and *šipur* 'improvement', have in common a set of consonants, but their vowels differ (vowel changes are a means of indicating derivational relations, which we will not be concerned with).

4.3. Phonological alternations

Voicing assimilation. As for the choice between an underlying voiced or voiceless consonant, scanning the data reveals that a voiced consonant appears before voiced obstruents and a voiceless consonant appears before voiceless obstruents and sonorants. Since sonorants are phonetically voiced, it is clear that there is no natural context for deriving the voiceless consonant [t], so we assume that the prefix is underlyingly /it/. Before a voiced obstruent, a voiceless obstruent becomes voiced.

(45) $[\text{-sonorant}] \rightarrow [\text{+voice}] \;/\; \underline{\quad\quad}\; \begin{matrix} C \\ \begin{bmatrix} \text{-son} \\ \text{+voi} \end{bmatrix} \end{matrix}$

Alternations in V_2. The second vowel of the stem has three phonetic variants: [a] as in *itparn**a**sti*, [e] as in *itparn**e**s*, and ∅ as in *idbad**r**u* (cf. *idbad**e**r*). Deletion of

the second stem vowel only takes place before the suffix *-u*, so we will first attempt to decide when the vowel is deleted. A partial specification of the context for vowel deletion is before C+V, which explains why the 1 sg. and 2 sg. masc. forms (with the suffixes *-ti* and -∅) do not undergo vowel deletion. The next step in determining when a vowel is deleted is to sort the examples into two groups: those with vowel deletion, and those with no vowel deletion. In the following examples, the site of vowel deletion (or its lack) is marked with an underscore.

(46) *Vowel deletion*

itħam_ku	itlap_šu	idbad_ru
idgar_šu	istap_ru	istar_ku
ištap_ru	itˢtal_mu	izdak_nu
izdar_zu	itmal_ʔu	itpal_ʔu
itnas_ʔu	itpat_ħu	idgal_ħu
itnatˢ_ħu	ištag_ʕu	itpar_ʕu

No vowel deletion

itparnesu	itparsemu	idbalbelu
idgalgelu	idarderu	itpalelu
itxamemu	itmotetu	itʔošešu
idbodedu	itamemu	

Based on this grouping, we discover a vowel is deleted when it is preceded by just a single consonant; if two consonants precede the vowel, there is no deletion.

However, it is not always the case that a vowel deletes after a single consonant, so our rule cannot simply look for one versus two consonants. There are cases such as *itʔošešu* where there is no vowel deletion, despite the fact that there is only a single consonant before the vowel. Inspecting all of those examples, we discover that the consonants preceding and following the vowel are the same, and in every case where a vowel is deleted, the preceding and following consonants are different. Thus, a vowel deletes only if it is preceded by a single consonant, and that consonant must be different from the consonant that follows the vowel (which is indicated informally as 'C_i...C_j' in the rule).

(47) $e \rightarrow \varnothing$ / V C_i ___ C_j V

At this point, we now recognize this process as a kind of syncope, a phonological rule which we have encountered many times before.

Closed syllable lowering. Now we turn to the alternation between [a] and [e]. Concentrating on the first set of examples in the dataset, we find [a] before CC (*itparnasti*), and [e] before C# or CV (*itparnes, itparnesu*). Assuming that this dis-

tribution is generally valid, we would therefore posit the following rule to derive [a] from /e/.

(48) e → a / __ CC

Note that an attempt to derive [e] from underlying /a/ runs into the difficulty that the context C# plus CV is not a conherent context, but is just a set of two partially related contexts. This motivates the decision to select underlying /e/.

In four examples, the second stem vowel /e/ appears as [a] before a single consonant, namely the 1 sg. forms *itmotati, idbodati, ištagati* and *itparati*. These examples fall into two distinct subgroups, as shown by looking at their underlying stems, which is revealed in the 3 sg. feminine forms (*itmotet-u, idboded-u* and *ištagʕu, itparʕu*). In the first two examples the stems underlyingly end in a coronal stop *t* or *d*, and in the second two examples the stems underlyingly end in the voiced pharyngeal *ʕ*. At the underlying level, the second stem vowel is followed by two consonants (/itmotetti/, /itbodedti/, /ištageʕti/ and /itpareʕti/). Surface [a] is explained on the basis of the underlying consonant cluster — it must simply be assured that the rules simplifying these clusters apply after (48).

In the first two examples (*itmotati* and *idbodati* from /itmotat-ti/ and /idbodad-ti/) combination of the 1 sg. suffix with the root would (after assimilation of voicing) be expected to result in **itmotatti* and **idbodatti*. In fact, the data provide no examples of geminate consonants, and where geminates might have been created by vowel syncope in *idbodedu*, syncope is blocked. Thus, the language seems to be pursuing a strategy of avoiding the creation of geminate consonants. We can account for this simplification of consonant clusters by the following rule.

(49) $\begin{Bmatrix} t \\ d \end{Bmatrix} \rightarrow \varnothing \,/\, \_\_ \begin{Bmatrix} t \\ d \end{Bmatrix}$ or $C_iC_i \rightarrow C_i$

The postulation of this degemination rule also explains *itamem* (cf. also *tamim*) and *idarder* (cf. also *dirdur*), where the stem begins with /t/ or /d/. The underlying forms of these verbs would be /it-tamem/ and /it-darder/: the surface form with a single consonant reflects the application of this consonant-degemination process.

Stems with final pharyngeals and laryngeals. The vowel quality of the underlying stems *šageʕ* and *pareʕ* will be left aside temporarily, since there seem to be a number of problems associated with these stems. We thus turn to the stems represented in *itpatakti, idgalakti* and *itnatˢakti*. What is problematic about these stems is the appearance of [ea] when no suffix is added, viz. *itpateak, idgaleak* and *itnatˢeak*. Assuming the underlying forms to be *itpatek, idgalek* and *itnatˢek* (selecting /e/ as the second vowel, analogous to *itparnes, itlabeš* and *idboded*) we would need a rule inserting the vowel [a]. These stems have in common that their final consonant is the pharyngeal [ħ], suggesting a rule along the following lines.

(50) ∅ → a / e __ ħ

Why does this rule only apply in the suffixless 2 sg. masc. form? When the stem is followed by -*u*, the vowel /e/ is deleted by the syncope rule, therefore there is no vowel before *ħ*. Syncope does not apply before the suffix -*ti*, but there is still no epenthetic vowel. The reason is that underlying /e/ changes to [a] by rule (48), before a cluster of consonants. Since that rule changes /e/ to *a* but (50) applies after *e*, prior application of (50) deprives vowel insertion of a chance to apply.

Now returning to the stems *šageʕ* and *pareʕ*, we can see that this same process of vowel insertion applies in these stems in the 2 sg. masc. Starting from /ištageʕ/ and /itpareʕ/, vowel epenthesis obviously applies to give intermediate *ištageaʕ* and *itpareaʕ*. This argues that the epenthesis rule should be generalized so that both of the pharyngeal consonants trigger the process.

(51) ∅ → V / e __ C
[+low] [+low]

The forms derived by (51) are close to the actual forms, which lack the consonant ʕ, and thus with an appropriate consonant deletion rule we can finish the derivation of these forms. To formalize this rule, we need to determine where the consonant ʕ appears in the language: our data indicates that it appears only before a vowel, never before a consonant or at the end of a word which is to say it never appears at the end of a syllable). Knowing this generalization, we posit the following rule.

(52) ʕ → ∅ / ___ {C,#}

No further rules are needed to account for this set of examples. In *ištagati* and *itarati*, from *ištageʕti* and *itpareʕti*, there is no epenthetic vowel. This is predicted by our analysis, since these verbs must undergo the rule lowering /e/ to [a] before CC, and as we have just argued, vowel lowering precedes vowel epenthesis (thus preventing epenthesis from applying). In this respect, *ištagati* and *itparati* are parallel to *itpateaħ, idgaleaħ* and *itnatˢeaħ*. The non-parallelism derives from the fact that syllable-final ʕ is deleted, so predicted *ištagaʕti* and *itparaʕti* are realized as *ištagati* and *itparati* thanks to this deletion.

The final set of verb stems typified by the verb *itmaleti* ~ *itmale* ~ *itmalʔu* exbibits a glottal stop in some contexts and ∅ in other contexts. The two most obvious hypotheses regarding underlying form are that the stem is /male/, or else /maleʔ/. It is difficult to decide between these possibilities; we will explore both possibilities. Suppose, first, that these stems end in glottal stop. In that case, we need a rule deleting glottal stop syllable finally — a similar rule was required to delete the consonant ʕ. A crucial difference between stems ending in ʕ and stems presumably ending in *ʔ* is that the stem vowel /e/ does not lower to [a] before -*ti* in

the latter set. Thus, deletion of *ʔ* would have to be governed by a different rule than deletion of ʕ, since *ʔ*-deletion precedes lowering and ʕ-deletion follows lowering.

An alternative that we want to consider is that these stems really end in a vowel, not glottal stop. Assuming this, surface [itpaleti] would simply reflect concatenation of the stem /pale/ with the suffix, and no phonological rule would apply. The problem is that we would also need to explain why the rule of syncope does not apply to [itpaleti], since the phonetic context for that rule is found here. The glottal-final hypothesis can explain failure of syncope rather easily, by ordering glottal stop deletion after syncope — when syncope applies, the form is /itpaleʔti/, where the consonant cluster blocks syncope.

Metathesis. The last point regarding the Hebrew data is the position of *t* in the prefix. The consonant of the prefix actually appears after the first consonant of the stem in the following examples.

(53)	istaparti	'get a haircut'	istarakti	'comb hair'
	ištaparti	'improve'	it^{s}talamti	'have photo taken'
	izdakanti	'age'	izdarasti	'hurry'

We would have expected forms such as [itsaparti], [itšaparti], [itt^{s}alamti] by just prefixing *it-* to the stem. A metathesis rule is therefore needed which moves *t* to be after these consonants. What makes this group of consonants — [s,š,t^{s},z] — a natural class is that they are all and only the strident coronals. We can thus formalize this rule as follows: a coronal stop followed by a coronal strident switch order.

(54) $$\begin{bmatrix} +\text{cor} \\ -\text{cont} \end{bmatrix} \begin{bmatrix} +\text{cor} \\ +\text{strid} \end{bmatrix} \rightarrow \begin{bmatrix} +\text{cor} \\ +\text{strid} \end{bmatrix} \begin{bmatrix} +\text{cor} \\ -\text{cont} \end{bmatrix}$$

The ordering of this metathesis rule with respect to the voicing assimilation rule is crucial. Given underlying /it-zakanti/, one might attempt to apply metathesis first, which would yield *iztakanti*, where voiceless *t* is placed after stem-initial *z*. The voicing assimilation rule (in a general form, applying between all obstruents) might apply to yield **istakanti*. So if metathesis applies before voicing assimilation, we will derive an incorrect result, either **iztakanti* if there is no voicing assimilation (assuming that the rule only turns voiceless consonants into voiced ones) or **istakanti* if there is voicing assimilation. However, we will derive the correct output if we apply voicing assimilation first: /itzakanti/ becomes *idzakanti*, which surfaces as [izdakanti] by metathesis. With this ordering, we have completed our analysis of Modern Hebrew phonology.

5. Japanese

The analysis of phonological alternations found in connection with the conjugation of verbs in Japanese provides our final illustration of the kinds of issues that must be considered in coming up with appropriate rules and underlying representations. In solving this problem, it is particularly important to make the correct assumptions about underlying representations, since the selection of underlying forms goes hand in hand with stating the rules correctly.

5.1. The data

The relevant data are given in (55).

(55)

present	*negative*	*volitional*	*past*	*inchoative*	*gloss*
neru	nenai	netai	neta	neyo:	sleep
miru	minai	mitai	mita	miyo:	see
šinu	šinanai	šinitai	šinda	šino:	die
yomu	yomanai	yomitai	yonda	yomo:	read
yobu	yobanai	yobitai	yonda	yobo:	call
kat^{s}u	katanai	kačitai	katta	kato:	win
kasu	kasanai	kašitai	kašita	kaso:	lend
waku	wakanai	wakitai	waita	wako:	boil
t^{s}ugu	t^{s}uganai	t^{s}ugitai	t^{s}uida	t^{s}ugo:	pour
karu	karanai	karitai	katta	karo:	shear
kau	kawanai	kaitai	katta	kao:	buy

5.2. Morphological analysis

We could make an initial guess regarding suffixes, which leads to the following hypotheses: -*u* = 'present', -*nai* = 'negative', -*tai* = 'volitional', -*ta* = 'past' and -*yo:* = 'inchoative': that analysis seems reasonable given he first two verbs in the data. We might also surmise that the root is whatever the present tense form is without the present ending, i.e. underlying *ner, mir, šin, yom, yob, kat^{s}, kas, wak, t^{s}ug, kar*, and *ka*. In lieu of the application of a phonological rule, the surface form of a word should simply be whatever we hypothesize the underlying form of the root to be, plus the underlying form of added affixes. Therefore, given our preliminary theory of roots and suffixes in Japanese, we predict the following surface forms, with hyphens inserted between morphemes to make the division of words into roots and suffixes clear.

(56) **Predicted surface forms**

present	*negative*	*volitional*	*past*	*inchoative*
ner-u	ner-nai	ner-tai	ner-ta	ner-yo:
mir-u	mir-nai	mir-tai	mir-ta	mir-yo:
šin-u	šin-nai	šin-tai	šin-ta	šin-yo:
yom-u	yom-nai	yom-tai	yom-ta	yom-yo:
yob-u	yob-nai	yob-tai	yob-ta	yob-yo:
kat^s-u	kat^s-nai	kat^s-tai	kat^s-ta	kat^s-yo:
kas-u	kas-nai	kas-tai	kas-ta	kas-yo:
wak-u	wak-nai	wak-tai	wak-ta	wak-yo:
t^{s}ug-u	t^{s}ug-nai	t^{s}ug-tai	t^{s}ug-ta	t^{s}ug-yo:
kar-u	kar-nai	kar-tai	kar-ta	kar-yo:
ka-u	ka-nai	ka-tai	ka-ta	ka-yo:

The forms which are correct as is are underlined: as we can see, all of the present tense forms are correct, and none of the others are. It is no surprise that the present tense forms are correct, since we decided that the underlying form of the root is whatever we find in the present tense minus the vowel *-u*. It is possible, but unlikely, that every other word undergoes some phonological rule.

Changing our hypothesis. Since our first guess about underlying forms is suspect, we should consider alternative hypotheses. Quite often, the cause of analytic problems is incorrect underlying forms. One place to consider revising the assumptions about underlying representations would be in the underlying forms of the affixes. It was assumed — largely on the basis of the first two forms *nenai* and *minai* — that the negative suffix is underlyingly *-nai*. However, in most of the examples, this apparent suffix is preceded by the vowel *a* (*šinanai, yomanai, yobanai* and so on), which suggests the alternative possibility that the negative suffix is really *-anai*. Similarly, the decision that the volitional suffix is underlyingly *-tai* is justified based on the fact that it appears as *-tai* in the first two examples; however, the suffix is otherwise always preceded by the vowel *i* (*šinitai, yomitai, yobitai* and so on), so this vowel might analogously actually be part of the suffix.

A fact strongly suggests that the initial hypothesis about the underlying forms of suffixes was incorrect. The past tense suffix, which we also assumed to be *-ta*, behaves very differently from the volitional suffix, and thus we have *šinitai* versus *šinda, yomitai* versus *yonda, kačitai* versus *katta, karitai* versus *katta* (there *are* similarities such as *kašitai* and *kašita* which must also be accounted for). It is quite unlikely that we can account for these very different phonological patterns by reasonable phonological rules if we assumes that the volitional and past tense suffixes differ solely by the presence of final *i*. It is this realization, that there is a basic divergence between the past tense and volitional suffixes in terms of how they act phonologically, that provides the key to identifying the right underlying forms. Given how similar these two suffixes are in surface forms, -(*i*)*tai* vs. -(*i*)*ta*, but

how differently they behave, they must have quite different underlying forms. Since the past tense suffix rarely has a vowel and the volitional suffix usually does, we modify our hypothesis so that the volitional is /-itai/ and the past tense is /ta/. Because the negative acts very muct like the volitional in terms of where it has a vowel, we also adopt the alternative that the nagative is /anai/.

These changed assumptions about underlying representations of suffixes yield a significant improvement in the accuracy of our predicted surface forms, as indicated in (57), with correct surface forms underlined.

(57) **Modified predicted surface forms**

present	*negative*	*volitional*	*past*	*inchoative*
ner-u	ner-anai	ner-itai	ner-ta	ner-yo:
mir-u	mir-anai	mir-itai	mir-ta	mir-yo:
šin-u	šin-anai	šin-itai	šin-ta	šin-yo:
yom-u	yom-anai	yom-itai	yom-ta	yom-yo:
yob-u	yob-anai	yob-itai	yob-ta	yob-yo:
kat^{s}-u	kat^{s}-anai	kat^{s}-itai	kat^{s}-ta	kat^{s}-yo:
kas-u	kas-anai	kas-itai	kas-ta	kas-yo:
wak-u	wak-anai	wak-itai	wak-ta	wak-yo:
t^{s}ug-u	t^{s}ug-anai	t^{s}ug-itai	t^{s}ug-ta	t^{s}ug-yo:
kar-u	kar-anai	kar-itai	kar-ta	kar-yo:
ka-u	ka-anai	ka-itai	ka-ta	ka-yo:

Implicitly, we know that forms such as predicted *[kat^{s}anai] (for [katanai]) and *[kas-itai] (for [kašitai]) must be explained, either with other changes in underying forms, or by hypothesizing rules.

We will consider one further significant modification of the underlying representations, inspired by the success that resulted from changing our assumptions about -*itai* and -*anai*, in reducing the degree to which underlying and surface forms differ. The original and dubious decision to treat these suffixes as *tai* and *nai* was influenced by the fact that that is how they appear with the first two verbs. It is also possible that our initial hypothesis about the underlying form of these two verb roots was incorrect. There is good reason to believe that those assumptions were indeed also incorrect. Compare the surface form of the three verbs in our dataset which, by hypothesis, have roots ending in *r*.

(58)

present	*negative*	*volitional*	*past*	*inchoative*	*gloss*
ner-u	ne-nai	ne-tai	ne-ta	ne-yo:	sleep
mir-u	mi-nai	mi-tai	mi-ta	mi-yo:	see
kar-u	kar-anai	kar-itai	katt-a	kar-o:	shear

Clearly, the supposed roots /ner/ and /mir/ act quite differently from /kar/. The consonant *r* actually surfaces in most of the surface forms of the verb ‘shear’,

whereas *r* actually only appears in 'sleep' and 'see' in the present tense. In other words, there is little reason to believe that the first two roots are really /ner/ and /mir/, rather than /ne/ and /mi/: in contrast, there seems to be a much stronger basis for saying that 'shear' is underlyingly /kar/. Now suppose we change our assumption about these two verbs, and assume that these verb roots end in vowels.

(59) **Modified predicted surface forms**

present	*negative*	*volitional*	*past*	*inchoative*
ne-u	ne-anai	ne-itai	ne-ta	ne-yo:
mi-u	mi-anai	mi-itai	mi-ta	mi-yo:
šin-u	šin-anai	šin-itai	šin-ta	šin-yo:
yom-u	yom-anai	yom-itai	yom-ta	yom-yo:
yob-u	yob-anai	yob-itai	yob-ta	yob-yo:
kat^{s}-u	kat^{s}-anai	kat^{s}-itai	kat^{s}-ta	kat^{s}-yo:
kas-u	kas-anai	kas-itai	kas-ta	kas-yo:
wak-u	wak-anai	wak-itai	wak-ta	wak-yo:
t^{s}ug-u	t^{s}ug-anai	t^{s}ug-itai	t^{s}ug-ta	t^{s}ug-yo:
kar-u	kar-anai	kar-itai	kar-ta	kar-yo:
ka-u	ka-anai	ka-itai	ka-ta	ka-yo:

In terms of being able to predict the surface forms of verbs without phonological rules, this has resulted in a slight improvement of predictive power (sometimes involving a shuffling of correct and incorrect columns, where under the current hypothesis we no longer directly predict the form of the present tense, but we now can generate the past and inchoative forms without requiring any further rules). More important is the fact that we now have a principled basis, in terms of different types of underlying forms, for predicting the different behavior of the verbs which have the present tense *neru, miru* versus *karu*, which are in the first two cases actually vowel-final roots, in contrast to a consonant-final root.

5.3. Phonological rules

At this point, we will attempt to discover phonological rules which explain remaining differences between underlying and surface forms — though it always remains possible that we will need to change our assumed underlying forms, as our analysis progresses. The approach to take is to look at forms which are still not completely explained, and construct hypotheses to account for these forms: what new rules are needed to get from the underlying to surface forms. One useful way to approach this is to look for columns or rows of data where similar things seem to be happening. The incorrectly predicted forms are re-listed below, this time excluding the forms which are already explained, with information about the nature of the problem added. If a segment is predicted but does not actually surface, that segment is placed in parentheses; if there is a segment which appears in the surface

form but which does not appear to be present in the underlying form, the segments is placed in square brackets; segments whose phonetic quality differs from the predicted quality are italicized.

(60)

present	*negative*	*volitional*	*past*	*inchoative*	
ne[r]u	ne(a)nai	ne(i)tai			sleep
mi[r]u	mi(a)nai	mi(i)tai			see
			šin*t*a	šin(y)o:	die
			yo*mt*a	yom(y)o:	read
			yo*bt*a	yob(y)o:	call
	ka*t*ˢanai		ka*t*ˢta	ka*t*ˢ(y)o:	win
		ka*s*itai	ka*s*[i]ta	kas(y)o:	lend
			wa*k*ta	wak(y)o:	boil
			tˢug*t*a	tˢug(y)o:	pour
			ka*r*ta	kar(y)o:	shear
	ka(w)anai		ka[t]ta	ka(y)o:	buy

The glide in the inchoative. In order to explain most of the problems which arise with the inchoative form, we will consider the possibility that there is a rule deleting consonants after consonants, since that is the nature of the problem with the inchoative colum. Such a consonant deletion cannot be totally general, i.e. deleting any consonant after any other consonant, since as is evident in the past tense column, the consonant clusters [tt] and [nd] are possible in the language. Nevertheless, this is a rather restricted subset of the imaginable two-consonant combinations which can be formed from the consonants of the language, and this is a good indication that there may be some process deleting a consonant after another consonant. Thus we might assume a rule deleting the glide *y* after a consonant.

(61) $$\begin{bmatrix} \text{- cons} \\ \text{- back} \end{bmatrix} \rightarrow \varnothing \,/\, \text{C}\_\_$$

The postulation of any such rule immediately makes a prediction about possible surface forms: there should be no sequences of consonant plus glide in the data. Since there are none in the data at hand, our hypothesis has passed an important test. (If you know Japanese, you may know of words with *y* after a consonant, e.g. [To:kyo:]. We will restrict ourselves to the specific dataset given here, but the restriction on the rule that the deleted consonant must be morpheme-initial solve this problem). Armed with this rule, we have now accounted for a very large chunk of otherwise problematic examples — all of the inchoative forms except for *kao:* 'buy', where the glide deletes but there seems to be no consonant which would condition deletion of the glide.

Vowel deletion. Another area where some success is possible in reconciling underlying and surface forms by focusing on possible segment sequences is with the verbs 'sleep' and 'see'. The difference between the predicted (*neanai, mianai; neitai, miitai*) and actual forms (*nenai, minai; netai, mitai*) of the negative and volitional forms is that the actual forms lack the suffix vowel. In the predicted forms, we find a sequence of vowels, whereas in the actual form, only the first of those vowels is found. This raises the question whether we might postulate a rule deleting a vowel after another vowel. In positing such a rule, we would want to consider what V-V sequences are actually found in the data. We find the vowel sequences [ai] in the volitional and negative suffixes itself, as well as in past tense *waita*; also [ui] in the past of 'pour'; also the sequences [ao:] and [au] in the verb 'buy'. We do not find sequences of vowels containing the front vowels [e] or [i], that is, the otherwise expected sequences [ia], [ii], [ea] and [ei]. Therefore, we posit the following rule of vowel deletion.

(62) $$V \rightarrow \varnothing \,/ \begin{bmatrix} +\text{syl} \\ -\text{back} \end{bmatrix} \_\_$$

This resolves many of the problematic forms of the verbs 'sleep' and 'die', for example the fact that /ne-itai/ → [netai], but there are still some examples that we still cannot explain. In the present tense, we find [neru] and [miru], which we presume derives from /ne-u/ and /mi-u/. The vowel deletion rule (62) should apply to these underlying forms, resulting in incorrect *[ne] and *[mi]. We might try to resolve this by assuming that the vowel [u] cannot be deleted by (62) — we would then need to restricting the rule to exclude round vowels from deletion. If /u/ fails to be deleted in /ne-u/, perhaps a consonant is inserted thereby eliminating the cluster of vowels.

We will consider another possibility later, that the present suffix is /ru/, so rather than inserting it in *neru*, we delete it in [yomu].

(63) $$\varnothing \rightarrow r \,/ \begin{bmatrix} +\text{syl} \\ -\text{back} \end{bmatrix} \_\_ \; V$$

Armed with these new rules, we will have actually accounted for all forms of the verbs 'sleep' and 'see'.

Nasal + consonant. At this point, the remaining problem forms have been reduced to a very small set, mostly in the past tense. A comparison of the presumed underlying and surface past tense forms is given below.

(64)	/šinta/	[šinda]	/yomta/	[yonda]
	/yobta/	[yonda]	/kat^{s}ta/	[katta]
	/kasta/	[kašita]	/wakta/	[waita]
	/t^{s}ugta/	[t^{s}uida]	/karta/	[katta]
	/kata/	[katta]		

The problem posed by the past tense form is that by combining the root with the suffix *-ta*, underlying clusters of consonants would be created, but there are very severe restrictions on what consonant clusters exist in Japanese. The simplest problem is that presented by [šinda] from /šinta/, where /t/ becomes voiced after a nasal. A process of post-nasal voicing is rather common in the languages of the world, so we may hypothesize that there is such a process in Japanese.

(65) C → [+voice] / [+nasal] ___

The data further suggest that the rule applies in other examples, since we see that in the past tense of the roots /yom/ and /yob/, the final consonant of the root is a nasal on the surface, and /t/ becomes voiced.

Having noticed that the set of surface consonant clusters is very restricted, we can account for the problem of the verbs /yob/ and /yom/ as well, by noting that the final consonant in these roots becomes [n], which is part of the change from the nonexistent sequences /mt/ and /bt/ to the actually occurring [nd]. Thus, these consonants become [n] before /t/ (and subsequently, /t/ voices after the derived [n]).

(66) $$[\text{-coronal}] \rightarrow \begin{bmatrix} \text{+ coronal} \\ \text{+ nasal} \end{bmatrix} / \_\_\_\ \text{C}$$

Notice that although the data only illustrate preconsonantal nasalization before /t/, the rule is stated as generally as possible, thus predicting that if a suffix beginning with /k/ or /d/ were found, nasalization would take place there as well.

Always on the watch for other contexts where the same general phenomenon seems to be relevant to more than one form, we also notice that the surface forms [waita] and [t^{s}uida] differ from their underlying forms /wakta/ and /t^{s}ugta/ by replacing the preconsonantal velar with the vowel [i], suggesting a vocalization rule such as the following.

(67) $$\begin{array}{ccc} \text{C} & & \text{V} \\ [\text{+hi}] & \rightarrow & [\text{-back}] \quad / \_\_\_\ \text{C} \end{array}$$

This rule straightforwardly accounts for the form [waita], and almost accounts for the form [t^{s}uida], except that we still need to explain why the suffix consonant is voiced. The underlying representation itself provides a reason for this

voicing, since underlyingly, /t/ is preceded by a voiced consonant in /tˢugta/. We know that /t/ voices in another context, after a nasal, so we could account for voicing in [tˢuida] by re-stating the rule so that it applies not just after nasals (which are voiced), but after all voiced consonants. By applying the voicing rule which is sensitive to underlying consonant voicing before the velar-vocalization rule, we can explain the opaque surface difference [waita] versus [tˢuida], as deriving from the voicing of the consonant which precedes it underlyingly. We also want to be sure to apply rule (67) before rule (66), given the way we have formulated these rules. We did not explicitly restrict (66), which changes non-coronals to [n] before a consonant, to applying only to labials. Therefore, the more specific rule (67) must apply first, otherwise velars would also be incorrectly turned into [n] before a consonant.

5.4. Taking stock

At this point, it is useful to review the present state of our analysis. We have posited six phonological rules — y-deletion, vowel-deletion, r-insertion, consonant voicing, velar vocalization, and labial nasalization — which, given the assumptions that we have made regarding roots and suffixes, account for most of the forms in the dataset. It is important to recheck the full dataset against our rules, to be certain that our analysis does handle all of the data. A few forms remain which we cannot fully explain.

The forms which we have not yet explained are the following. First, we have not explained the variation in the root-final consonant seen in the verb 'win' (*katˢ-u, kat-anai, kač-itai, kat-ta, kat-o:*). Second, we have not accounted for the variation between *s* and *š* in the verb 'shear', nor have we explained the presence of the vowel [i] in the past tense of this verb. Finally, in the verb 'buy' we have not explained the presence of [w] in the negative, the appearance of a second [t] in the past tense form, and we have not explained why in the inchoative form [kao:] the suffix consonant *y* deletes.

Correcting the final consonant. The first problem to take on is the variation in the final consonant of 'win'. Looking at the correlation between the phonetic realization of the consonant and the following segment, we see that [tˢ] appears before [u], [č] appears before [i], and [t] appears elsewhere. Obviously, then, it was a mistake to assume that the underlying form of this root contains the consonant /tˢ/; instead, we will assume that the underlying consonant is /t/ (and therefore nothing more needs to be said about the surface forms *kat-anai, kat-ta*, and *kat-o:*). Looking more generally at the distribution of [č] and [tˢ] in the data, [č] only appears before [i], and [tˢ] only appears before [u], allowing us to posit the following rules.

(68) t → [+delayed release] / __ u

(69) $$t \rightarrow \begin{bmatrix} + \text{del.rel} \\ - \text{anterior} \end{bmatrix} / \_\_ i$$

Moving to the verb 'lend', we find a related problem that the final consonant /s/ appears as surface [š] before the vowel [i]. This is reminiscent of the process which we assumed turning *t* into *č* before *i*. In fact, we can decompose the process *t* → *č* into two more basic steps: /t/ becomes an affricate before [i], and *s* and t^s become alveopalatal [š] and [č] before the vowel [i].

i-epenthesis. All that remains to be explained about 'lend' is why [i] appears in the past tense, i.e. why does /kasta/ become *kasita* (whence [kašita])? This is simple: we see that [st] does not exist in the language, and no assimilations turn it into an existing cluster, so [i] is inserted to separate these two consonants.

(70) $$\varnothing \rightarrow \begin{bmatrix} + \text{syl} \\ + \text{hi} \\ - \text{back} \end{bmatrix} / \begin{bmatrix} + \text{cont} \\ - \text{son} \end{bmatrix} \_\_ \begin{bmatrix} + \text{cor} \\ - \text{cont} \end{bmatrix}$$

r-assimilation and final w. Turning now to the form [katta] 'shear (past)' from /kar-ta/, a simple assimilation is needed to explain this form:

(71) $$r \rightarrow C_i / \_\_ C_i$$

The last remaining problems are in the verb 'buy', where we must explain the extra [t] in [katta], the presence of [w] in [kawanai], and the loss of /y/ in the inchoative form [kao:]. We might explain the form [kawanai] by a rule of *w*-insertion inserting *w* between two occurrences of the vowel [a]; more puzzling is the form [katta], which we presume derives from /ka-ta/. It would be very unusual for a consonant to spontaneously double between vowels. Since there are so many problems associated with this one root, perhaps the problem lies in our assumptions about the underlying form of this root. Perhaps the *w* in [kawanai] is part of the root itself. What would be the benefit of assuming that this root is really /kaw/? First, it explains the presence of *w* in [kawanai]. Second, it provides a basis for the extra [t] in [katta]: /w/ assimilates to following [t]. Such an assimilation is implicit in our analysis, namely rule (71) assimilating /r/ to /t/. We can generalize this rule to applying to both /r/ and /w/, which are oral sonorant. Finally, positing underlying /kaw/ helps to resolve the mystery of why /y/ deletes in the inchoative form [kao:], when otherwise /y/ only deletes when it is preceded by a consonant. If we start with /ka-yo:/ there is no reason for /y/ to delete, but if we start with /kaw-yo:/, /y/ is underlyingly preceded by a consonant /w/, which causes deletion of *y*, and then /w/ itself is deleted.

The cost of this analysis — a small cost — is that we must explain why [w] does not appear more widely in the root, specifically, why do we not find surface [w] in *ka-u*, *ka-itai* and *ka-o:*. The answer lies in the context where [w] appears: [w] only appears before a low vowel, suggesting the following rule.

(72) $$w \rightarrow \varnothing \,/\, \_\_ \begin{bmatrix} V \\ \text{- low} \end{bmatrix}$$

At this point, we have a complete analysis of the data. The rules (in shorthand versions) and underlying forms are recapitulated below.

(73) *Roots*:
/ne/ 'sleep', /mi/ 'see', /šin/ 'die', /yom/ 'read', /yob/ 'call', /kat/ 'win', /kas/ 'lend', /wak/ 'boil', /t^{s}ug/ 'pour', /kar/ 'shear', /kaw/ 'buy'

Suffixes:
-*u* 'present', -*anai* 'negative', -*itai* 'volitional', -*ta* 'past', -*yo:* 'inchoative'

Rules:

y → ∅ / C__	V → ∅ / e,i ___
∅ → r / e,i __ V	[-round]
b,m → n / __ t	k,g → i / ___ t
t → t^s / __ u,i	t^s,s → č,š / __ i
∅ → i / s __t	r,w → t / __ t
w → ∅ /__ V	t → d / C ___
[-lo]	[+voi]

Progress by hypothesis forming and testing. Three important points have emerged as our analysis developed. First, analysis procedes step-by-step, by forming specific hypotheses which we then check against the data, revising those hypotheses should they prove to be wrong. Second, it is vital to consider more than one hypothesis: if we had only pursued the first hypothesis that the roots /ne/, /mi/, /kar/ and /kaw/ were really underlying /ner/, /mir/, /kar/ and /ka/, we would never have been able to make sense of the data. The most important skill that you can bring to the task of problem-solving is the ability to create and evaluate competing hypotheses intended to explain some fact. Finally, it is particularly important to remember that assumptions about underlying representations go hand-in-hand with the phonological rules which you postulate for a language. When you check your solution, the problem may not be that your rules are wrong, but that your underlying forms are wrong. By continuously reviewing the analysis, and making sure that the rules works and your assumptions about underlying forms are consistent, you

should arrive at the stage that no further improvements to the analysis are possible, given the data available to you.

At this point, it might occur to you that there are aspects of the underlying representation which could still be questioned. Consider the present tense form, which we assumed was /u/. An alternative may be considered, where this suffix is really underlyingly /ru/. The presence of underlying /r/ in this suffix is made plausible by the fact that *r* actually appears in the forms *miru*, *neru*. We assumed that *r* is epenthetic, but perhaps it is part of the present suffix. That would allow us to eliminate the rule of *r*-epenthesis needed only to account for [neru] and [miru]. At the same time, we can also simplify the rule of vowel deletion, by removing the restriction that only non-round vowels delete after [e] and [i]: we made that assumption only because /ne-u/ and /mi-u/ apparentlu did not undergo the process of vowel deletion.

Any change in assumptioned underlying forms requires a reconsideration of those parts of the analysis relevant to that morpheme. We would then assume the underlying forms /šin-ru/, /yom-ru/, /kat-ru/ and so on, with the root final consonant being followed by /r/. This /r/ must be deleted: notice that we already have a rule which, stated in a more general form, would delete this /r/, namely the rule deleting /y/ after a consonant.

(74) [+sonor] → ∅ / C ___

If we generalize that rule to apply to any sonorant consonant after a consonant, we eliminate the rule of *r*-insertion, generalize the rules *y*-deletion and vowel-deletion, which results in a better analysis.

Summary

Analyzing a complex set of data into a consistent system of underlying representations and rules requires you to pay attention to details. A solution to a problem requires that you formulate reasoned hypotheses and test them against the data. The most important skill needed to test a hypothesis is that you must apply your rules completely literally. Do what the rule says must be done, and if that does not give you the correct result, you must change your underlying representations, rules, or rule ordering. The ability to consider multiple hypotheses is one of the most important skills in problem solving.

Exercises

1: Serbo-Croatian

These data from Serbo-Croatian have been simplified in two ways, to make the problem more manageable. Vowel length is omitted, and the only accentual property that is included is the predictable accent (whose location varies according to a rule). Invariant lexical acent is not marked, and your analysis should explain how accent is assigned in the predictable-accent class, where accent is marked. You cannot write rules which predict accent for those words in the unpredictable accent class, and you cannot (and should not try to) write a rule which somehow predicts *whether* a word receives a predictable accent. In other words, write one or more rules which assigns accent to the syllable marked with accent, and ignore the accent of words with no accent mark (however, other parts of the phonology of such words must be accounted for). Past tense verbs all have the same general past tense suffix, and that the difference between masculine, feminine and neuter past tense involves the same suffixes as are used to mark gender in adjectives.

Adjectives				
Masc.	*Fem.*	*Neut.*	*Pl.*	
mlád	mladá	mladó	mladí	young
púst	pustá	pustó	pustí	empty
bogat	bogata	bogato	bogati	rich
béo	belá	beló	belí	white
veseo	vesela	veselo	veseli	gay
debéo	debelá	debeló	debelí	fat
mío	milá	miló	milí	dear
zelén	zelená	zelenó	zelení	green
kradén	kradená	kradenó	kradení	stolen
dalék	daleká	dalekó	dalekí	far
visók	visoká	visokó	visokí	high
dubók	duboká	dubokó	dubokí	deep
križan	križana	križano	križani	cross
sunčan	sunčana	sunčano	sunčani	sunny
svečan	svečana	svečano	svečani	formal
bogat	bogata	bogato	bogati	rich
rapav	rapava	rapavo	rapavi	rough
yásan	yasná	yasnó	yasní	clear
vážan	važná	važnó	važní	important
sítan	sitná	sitnó	sitní	tiny
ledan	ledna	ledno	ledni	frozen
tának	tanká	tankó	tankí	slim
krátak	kratká	kratkó	kratkí	short

blízak	bliská	bliskó	bliskí	close
úzak	uská	uskó	uskí	narrow
dóbar	dobrá	dobró	dobrí	kind
óštar	oštrá	oštró	oštrí	sharp
bodar	bodra	bodro	bodri	alert
ustao	ustala	ustalo	ustali	tired
múkao	muklá	mukló	muklí	hoarse
óbao	oblá	obló	oblí	plump
pódao	podlá	podló	podlí	base

Verbs

1sg pres	*masc. past*	*fem. past*	*neut. past*	
tepém	tépao	teplá	tepló	wander
skubém	skúbao	skublá	skubló	tear
tresém	trésao	treslá	tresló	shake
vezém	vézao	vezlá	vezló	lead

2: Standard Ukrainian

Standard Ukrainian has palatalized and non-palatalized consonants. However, palatalized consonants do not appear before *e*. Consonants are generally palatalized before *i*, but there are apparent exceptions such as *bil*^{y} 'ache', which need not be seen as exceptions, given the right analysis. Give ordered rules to account for the alternations of the following nouns. The alternation between *o* and *e* is limited to suffixes and does not occur in roots. Also for masculine nouns referring to persons the morpheme *ov/ev* is inserted between the root and the case suffix in the locative singular (see the examples 'son-in-law', 'grandfather'). The data are initially ambiguous as to whether or not the alternations between *o* and *i* and between *e* and *i* are to be implemented by the same rule. Consider both possibilities; give an argument for selecting one of these solutions.

Masculine nouns

Nom. sg.	*Dat. pl.*	*Dat. sg.*	*Loc. sg.*	*Gloss*
zub	zubam	zubov^{y}i	zub^{y}i	tooth
sv^{y}it	sv^{y}itam	sv^{y}itov^{y}i	sv^{y}it^{y}i	light
z^{y}at^{y}	z^{y}at^{y}am	z^{y}atev^{y}i	z^{y}atev^{y}i	son-in-law
koš^{y}il^{y}	košel^{y}am	košelev^{y}i	košel^{y}i	basket
zlod^{y}iy	zlod^{y}iyam	zlod^{y}iyev^{y}i	zlod^{y}iyev^{y}i	thief
m^{y}is^{y}at^{sy}	m^{y}is^{y}at^{sy}am	m^{y}is^{y}at^{s}ev^{y}i	m^{y}is^{y}at^{sy}i	month
korovay	korovayam	korovayevi	korovayi	round loaf
kam^{y}in^{y}	kamen^{y}am	kamenev^{y}i	kamen^{y}i	stone
m^{y}id^{y}	m^{y}id^{y}am	m^{y}idev^{y}i	m^{y}id^{y}i	copper
xl^{y}iv	xl^{y}ivam	xl^{y}ivov^{y}i	xl^{y}iv^{y}i	stable
holub	holubam	holubov^{y}i	holub^{y}i	dove

s^{y}in	s^{y}inam	s^{y}inov^{y}i	s^{y}in^{y}i	son
leb^{y}id^{y}	lebed^{y}am	lebedev^{y}i	lebed^{y}i	swan
sus^{y}id	sus^{y}idam	sus^{y}idov^{y}i	sus^{y}idov^{y}i	neighbor
čolov^{y}ik	čolov^{y}ikam	čolov^{y}ikov^{y}i	čolov^{y}ik^{y}i	man
l^{y}id	ledam	ledov^{y}i	led^{y}i	ice
bil^{y}	bol^{y}am	bolev^{y}i	bol^{y}i	ache
riw	rovam	rovov^{y}i	rov^{y}i	ditch
stiw	stolam	stolov^{y}i	stol^{y}i	table
d^{y}id	d^{y}idam	d^{y}idov^{y}i	d^{y}idov^{y}i	grandfather
l^{y}it	l^{y}otam	l^{y}otov^{y}i	l^{y}ot^{y}i	flight
mist	mostam	mostov^{y}i	most^{y}i	bridge

Neuter nouns

Nom. sg.	*Gen. sg.*	*Dat. sg.*	*Loc. sg.*	*Gen. pl.*	*Gloss*
t^{y}ilo	t^{y}ila	t^{y}ilu	t^{y}il^{y}i	t^{y}iw	body
koleso	kolesa	kolesu	koles^{y}i	kol^{y}is	wheel
ozero	ozera	ozeru	ozer^{y}i	oz^{y}ir	lake
selo	sela	selu	sel^{y}i	s^{y}iw	village
pole	pol^{y}a	pol^{y}u	pol^{y}i	pil^{y}	field
slovo	slova	slovu	slov^{y}i	sliw	word
more	mor^{y}a	mor^{y}u	mor^{y}i	mir^{y}	sea

3: Somali

In the following Somali data, [ḍ] is a voiced retroflex stop and [ṛ] is a voiced retroflex spirant. Account for all phonological alternations in these data. In your discussion of these forms, be sure to make it clear what you assume the underlying representations of relevant morphemes are. Your discussion should also make it clear what motivates your underlying representations and rules. For instance if one might analyse some alternation by assuming underlying X and rule Y, say why (or whether) that choice is preferable to the alternative of assuming underlying P and rule Q.

Singular	*Sing. Definite*	*Plural*	*Gloss*
daar	daarta	daaro	house
gees	geesta	geeso	side
laf	lafta	lafo	bone
lug	lugta	luγo	leg
naag	naagta	naaγo	woman
tib	tibta	tiβo	pestle
sab	sabta	saβo	outcast
bad	bada	baðo	sea
ǰid	ǰida	ǰiðo	person
feeḍ	feeḍa	feeṛo	rib

ʕiir	ʕiirta	ʕiiro	buttermilk
ʔul	ʔuša	ʔulo	stick
bil	biša	bilo	month
meel	meeša	meelo	place
kaliil	kaliiša	kaliilo	summer
nayl	nayša	naylo	female lamb
sun	sunta	sumo	poison
laan	laanta	laamo	branch
sin	sinta	simo	hip
dan	danta	dano	affair
daan	daanta	daano	river bank
saan	saanta	saano	hide
nirig	nirigta	nirgo	baby female camel
gaβaḍ	gaβaḍa	gabḍo	girl
gǎjan	gǎjanta	gǎjmo	arm
hoɣol	hoɣoša	hoglo	downpour
baɣal	baɣaša	baglo	mule
waħar	waħarta	waħaro	female kid
irbad	irbada	irbaðo	needle
kefed	kefeda	kefeðo	pan
ǰilin	ǰilinta	ǰilino	female dwarf
bohol	bohoša	boholo	hole
jirid	jirida	jirdo	trunk
ʔaayad	ʔaayada	ʔaayaðo	miracle
gaʕan	gaʕanta	gaʕmo	hand
ʔinan	ʔinanta	ʔinano	daughter

3sg msc. pst	*3sg fem. past*	*1pl past*	*Gloss*
suɣay	sugtay	sugnay	wait
kaβay	kabtay	kabnay	fix
siðay	siday	sidnay	carry
dilay	dišay	dillay	kill
ganay	gantay	gannay	aim
tumay	tuntay	tunnay	hammer
argay	aragtay	aragnay	see
gudbay	guðubtay	guðubnay	cross a river
qoslay	qosošay	qosollay	laugh
hadlay	haðašay	haðallay	talk

4: Latin

Provide a complete account of the following phonological alternations in Latin, including underlying forms for nouns stems.

Nominative	*Genitive*	*Gloss*
arks	arkis	fortress
duks	dukis	leader
daps	dapis	feast
re:ks	re:gis	king
falanks	falangis	phalanx
filiks	filikis	fern
lapis	lapidis	stone
li:s	li:tis	strife
fraws	frawdis	deceit
noks	noktis	night
frons	frontis	brow
frons	frondis	leaf
inku:s	inku:dis	anvil
sors	sortis	lot
fu:r	fu:ris	thief
murmur	murmuris	murmur
augur	auguris	augur
arbor	arboris	tree
pugil	pugilis	boxer
sal	salis	salt
adeps	adipis	fat
apeks	apikis	top
pri:nkeps	pri:nkipis	chief
ekwes	ekwitis	horseman
miles	militis	soldier
no:men	no:minis	name
karmen	ka:rminis	song
lu:men	lu:minis	light
wenter	wentris	belly
pater	patris	father
kada:wer	kada:weris	corpse
tu:ber	tu:beris	swelling
piper	piperis	pepper
karker	karkeris	prison

The following five nouns and adjectives select a different genitive suffix, -*i:* as opposed to *is*. You cannot predict on phonological grounds what nouns take this suffix, but otherwise these words follow the rules motivated in the language.

li:ber	li:beri:	free
miser	miseri:	wretched
ager	agri:	field

sinister	sinistri:	left
liber	libri:	book

What other phonological rule or rules are needed to account for the following data?

as	assis	whole
os	ossis	bone
far	farris	spell
mel	mellis	honey
o:s	o:ris	mouth
flo:s	flo:ris	flower
mu:s	mu:ris	mouse
cru:s	cru:ris	leg
kinis	kineris	ash
pulvis	pulveris	dust

5: Turkish

Provide a phonological analysis of the following data from Turkish.

nom	*poss*	*dat*	*abl*	*nom. pl*	
oda	odasɨ	odaya	odadan	odalar	room
dere	deresi	dereye	dereden	dereler	river
ütü	ütüsü	ütüye	ütüden	ütüler	iron
balo	balosu	baloya	balodan	balolar	ball
arɨ	arɨsɨ	arɨya	arɨdan	arɨlar	bee
la:	la:sɨ	la:ya	la:dan	la:lar	la (note)
bina:	bina:sɨ	bina:ya	bina:dan	bina:lar	building
imla:	imla:sɨ	imla:ya	imla:dan	imla:lar	spelling
be:	be:si	be:ye	be:den	be:ler	B (letter)
kep	kepi	kepe	kepten	kepler	cap
at	atɨ	ata	attan	atlar	horse
ek	eki	eke	ekten	ekler	affix
ok	oku	oka	oktan	oklar	arrow
güč	güǰü	güǰe	gučten	gučler	power
ahmet	ahmedi	ahmede	ahmetten	ahmetler	Ahmed
kurt	kurdu	kurda	kurttan	kurtlar	worm
türk	türkü	türke	türkten	türkler	Turk
genč	genči	genče	genčten	genčler	young
halk	halkɨ	halka	halktan	halklar	folk
üst	üstü	üste	üstten	üstler	upper plane
sarp	sarpɨ	sarpa	sarptan	sarplar	steep
harp	harbɨ	harba	harptan	harplar	war
alt	altɨ	alta	alttan	altlar	bottom

renk	rengi	renge	renkten	renkler	color
his	hissi	hisse	histen	hisler	feeling
hür	hürrü	hürre	hürden	hürler	free
mahal	mahallɨ	mahalla	mahaldan	mahallar	place
hak	hakkɨ	hakka	haktan	haklar	right
zam	zammɨ	zamma	zamdan	zamlar	inflation
af	affɨ	affa	aftan	aflar	excuse
arap	arabɨ	araba	araptan	araplar	Arab
koyun	koyunu	koyuna	koyundan	koyunlar	sheep
pilot	pilotu	pilota	pilottan	pilotlar	pilot
kitap	kitabɨ	kitaba	kitaptan	kitaplar	book
domuz	domuzu	domuza	domuzdan	domuzlar	pig
davul	davulu	davula	davuldan	davullar	drum
bayɨr	bayɨrɨ	bayɨra	bayɨrdan	bayɨrlar	slope
somun	somunu	somuna	somundan	somunlar	loaf
fikir	fikri	fikre	fikirden	fikirler	idea
isim	ismi	isme	isimden	isimler	name
boyun	boynu	boyna	boyundan	boyunlar	neck
čevir	čevri	čevre	čevirden	čevirler	injustice
devir	devri	devre	devirden	devirler	transfer
koyun	koynu	koyna	koyundan	koyunlar	bosom
karɨn	karnɨ	karna	karɨndan	karɨnlar	thorax
burun	burnu	burna	burundan	burunlar	nose
akɨl	aklɨ	akla	akɨldan	akɨllar	intelligence
šehir	šehri	šehre	šehirden	šehirler	city
namaz	namazɨ	namaza	namazdan	namazlar	worship
zaman	zama:nɨ	zama:na	zamandan	zamanlar	time
harap	hara:bɨ	hara:ba	haraptan	haraplar	ruined
i:kaz	i:ka:zɨ	i:ka:za	i:kazdan	i:kazlar	warning
hayat	haya:tɨ	haya:ta	hayattan	hayatlar	life
ispat	ispa:tɨ	ispa:ta	ispattan	ispatlar	proof
inek	inei	inee	inekten	inekler	cow
mantɨk	mantɨɨ	mantɨa	mantɨktan	mantɨklar	logic
ayak	ayaɨ	ayaa	ayaktan	ayaklar	foot
čabuk	čabuu	čabua	čabuktan	čabuklar	quick
dakik	dakii	dakie	dakikten	dakikler	punctual
merak	mera:kɨ	mera:ka	meraktan	meraklar	curiosity
tebrik	tebri:ki	tebri:ka	tebrikten	tebrikler	greetings
hukuk	huku:ku	huku:ka	hukuktan	hukuklar	law

6: Kera

Propose ordered rules to account for the following alternations. It will prove useful to think about the vowels of this language in terms of high versus

non-high vowels. Also, in this language it would be convenient to assume that [h] and [ʔ] are specified as [+low]. In accounting for this data, it will be important to pay attention to both verbs like *bɨlan* 'want me', *balnan* 'wanted me' and *balla* 'you must want!', i.e. there are present, past and imperative forms involved, certain tenses being marked by suffixes. Finally, pay attention to what might look like a coincidence in the distribution of vowels in the underlying forms of verb roots: there are no coincidences.

haman	'eat me'	se:nen	'my brother'
hamam	'eat you m.'	se:nem	'your masc. brother'
hɨmi	'eat you f.'	si:ni	'your fem. brother'
hɨmu	'eat him'	si:nu	'his brother'
hama	'eat her'	se:na	'her brother'
hamaŋ	'eat you pl.'	se:neŋ	'your pl. brother'
kolon	'change me'	gi:din	'my belly'
kolom	'change you masc.'	gi:dim	'your masc. belly'
kuli	'change you fem.'	gi:di	'your fem. belly'
kulu	'change him'	gi:du	'his belly'
kola	'change her'	gi:dɨ	'her belly'
koloŋ	'change you pl.'	gi:diŋ	'your pl. belly'
cɨ:rɨn	'my head'	gunun	'wake me'
cɨ:rɨm	'your masc. head'	gunum	'wake you masc.'
ci:ri	'your fem. head'	guni	'wake you fem.'
cu:ru	'his head'	gunu	'wake him'
cɨ:rɨ	'her head'	gunɨ	'wake her'
cɨ:rɨŋ	'your pl. head'	gunuŋ	'wake you pl.'
bɨlan	'want me'	ŋɨfan	'meet me'
bɨlam	'want you masc.'	ŋɨfam	'meet you masc.'
bɨli	'want you fem.'	ŋɨfi	'meet you fem.'
bɨlu	'want him'	ŋɨfu	'meet him'
bɨla	'want her'	ŋɨfa	'meet her'
bɨlaŋ	'want you pl.'	ŋɨfaŋ	'meet you pl.'
ʔasan	'know me'	ʔapan	'find me'
ʔasam	'know you masc.'	ʔapam	'find you masc.'
ʔɨsi	'know you fem.'	ʔɨpi	'find you fem.'
ʔɨsu	'know him'	ʔɨpu	'find him'
ʔasa	'know her'	ʔapa	'find her'
ʔasaŋ	'know you pl.'	ʔapaŋ	'find you pl.'

haran	'give me back'
haram	'give you masc. back'
hɨri	'give you fem. back'
hɨru	'give him back'
hara	'give her back'
haraŋ	'give you pl. back'

balnan	'wanted me'	ŋafnan	'met me'
balnam	'wanted you masc.'	ŋafnam	'met you masc.'
bɨlni	'wanted you fem.'	ŋɨfni	'met you fem.'
bɨlnu	'wanted him'	ŋɨfnu	'met him'
balna	'wanted her'	ŋafna	'met her'
balnaŋ	'wanted you pl.'	ŋafnaŋ	'met you pl.'
balla	'you must want!'	ŋafla	'you must meet!'

ba	'not'	pa	'again'	bɨpa	'no more'

7: Keley-i

Account for the phonological alternations in the following inflected verbs. The different forms relate to whether the action is in the past or future, and which element in the sentence is emphasised (subject, object, instrument). Verb roots underlyingly have the shape CVC(C)VC, and certain tense forms such as the subject focus future require changes in the stem that result in a CVCCVC shape. This may be accomplished by reduplicating the initial CV- for stems whose first vowel is [e] as in *ʔum-bebhat* ← *behat*, or doubling the middle consonant as in *ʔum-buŋŋet* ← *buŋet*. The contrastive identification imperfective form similarly conditions lengthening of the consonant in the middle of the stem, when the first vowel is not [e], as in *memayyuʔ* ← *bayuʔ*. These changes should be treated as part of the morphology, so do not attempt to write phonological rules to double consonants or reduplicate syllables. Be sure to explicitly state the underlying form of each root.

subject focus future	*direct object focus past*	*instrumental focus past*	
ʔumduntuk	dinuntuk	ʔinduntuk	punch
ʔumbayyuʔ	binayuʔ	ʔimbayuʔ	pound rice
ʔumdillag	dinilag	ʔindilag	light lamp
ʔumgubbat	ginubat	ʔiŋgubat	fight
ʔumhullat	hinulat	ʔinhulat	cover
ʔumbuŋŋet	binuŋet	ʔimbuŋet	scold
ʔumgalgal	ginalgal	ʔiŋgalgal	chew
ʔumʔagtuʔ	ʔinagtuʔ	ʔinʔagtuʔ	carry on head
ʔumʔehneŋ	ʔinehneŋ	ʔinʔehneŋ	stand
ʔumbebhat	binhat	ʔimbehat	cut rattan

ʔumdedʔek	dinʔek	ʔindeʔek	accuse
ʔumtuggun	sinugun	ʔintugun	advise
ʔumtetpen	simpen	ʔintepen	measure
ʔumpeptut	pintut	ʔimpetut	dam
ʔumhehpuŋ	himpuŋ	ʔinhepuŋ	break a stick
ʔumtetkuk	siŋkuk	ʔintekuk	shout
ʔumkekbet	kimbet	ʔiŋkebet	scratch
ʔumbebdad	bindad	ʔimbedad	untie
ʔumdedgeh	diŋgeh	ʔindegeh	sick

instrumental past focus	*contrastive id. imperfective*	*contrastive id. perfective*	
ʔinduntuk	menuntuk	nenuntuk	punch
ʔimbayuʔ	memayyuʔ	nemayuʔ	pound rice
ʔindilag	menillag	nenilag	light lamp
ʔiŋgubat	meŋubbat	neŋubat	fight
ʔinhulat	menullat	nenulat	cover
ʔintanem	menannem	nenanem	plant
ʔimpedug	memdug	nemdug	chase
ʔimbedad	memdad	nemdad	untie
ʔiŋkebet	meŋbet	neŋbet	scratch
ʔimbekaʔ	memkaʔ	nemkaʔ	dig
ʔintepen	mempen	nempen	measure
ʔintebaʔ	membaʔ	nembaʔ	kill a pig
ʔintekuk	meŋkuk	neŋkuk	shout
ʔindegeh	meŋgeh	neŋgeh	sick
ʔinhepaw	mempaw	nempaw	possess
ʔinteled	menled	nenled	sting
ʔindeʔek	menʔek	nenʔek	accuse
ʔinʔebaʔ	meŋbaʔ	neŋbaʔ	carry on back
ʔinʔinum	meŋinnum	neŋinum	drink
ʔinʔagtuʔ	meŋagtuʔ	neŋagtuʔ	carry on head
ʔinʔalaʔ	meŋallaʔ	neŋalaʔ	get
ʔinʔawit	meŋawwit	neŋawit	get

The following past subject clausal focus forms involve a different prefix, using some of the roots found above. A number of roots require reduplication of the first root syllable.

nandunduntuk	'punch'	nampepedug	'chase'
naŋkekebet	'scratch'	nambebeka	'dig'
nantetekuk	'shout'	nandedeʔek	'accuse
nanʔeʔeba	'carry on back'	nanʔiʔinum	'drink'

nantanem 'plant'

8: Kikuria

In some (but not all) of the examples below, morphemes boundaries have been been introduced to assist in the analysis. There is a consonant dissimilation whereby $k \rightarrow g$ when the following consonant is voiceless, which may be disregarded here. Every noun is assigned to a grammatical class conventionally given a number (1-20), which is indicated by a particular prefix on the nouns (e.g. *omo-* for cl. 1); there are also pronoun prefixes on verbs marking subject and object for each class. Tones may be disregarded (however, it is completely predictable in the infinitive). It is important to pay attention to interaction between processes in this problem.

ogo-táángá	'to begin'	oko-gɛ́sa	'to harvest'
oko-rɔ́ga	'to witch'	oko-réma	'to plow'
oko-hóórá	'to thresh'	ugu-sííká	'to close a door'
ugu-súraangá	'to sing praise'	uku-gííngá	'to shave'
ugu-túúhá	'to be blunt'		

ogo-kó-bárǎ	'to count you (sg)'	uku-gú-súraánga	'to praise you (sg)'
oko-mó-bárǎ	'to count him'	uku-mú-súraánga	'to praise him'
ogo-tó-bárǎ	'to count us'	ugu-tú-súraánga	'to praise us'
oko-gé-bárǎ	'to count them (4)'	uku-gí-súraánga	'to praise it (4)'
oko-ré-bárǎ	'to count it (5)'	uku-rí-súraánga	'to praise it (5)'
uku-bí-bárǎ	'to count it (8)'	uku-bí-súraánga	'to praise it (8)'
uku-chí-bárǎ	'to count it (10)'	ugu-chí-súraánga	'to praise it (10)'

oko-mó-gó-gɛsɛ́ra	'to harvest it (3) for him'
uku-mú-gú-giíngíra	'to shave it (3) for him'
uku-mú-gú-siíkya	'to make him close it (3)'
uku-mú-gú-siíndya	'to make him win it (3)'
oko-bá-súraánga	'to praise them'
oko-mó-bá-suráángéra	'to praise them for him'
oko-bá-mú-suráángéra	'to praise him for them'

to V	*to make to V*	*to V for*	*to make V for*	
okoréma	ukurímyá	okoréméră	ukurímíryá	'weed'
okoróma	ukurúmyá	okoróméră	ukurúmíryá	'bite'
okohóórá	ukuhúúryá	okohóórérá	ukuhúúríryá	'thresh'
okohéétóká	ukuhíítúkyá	okohéétókerá	ukuhíítúkiryá	'remember'
okogéémbá	ukugíímbyá	okogéémbérá	ukugíímbíryá	'make rain'
ogosóóká	ugusúúkyá	ogosóókérá	ugusúúkíryá	'respect'
ogotégétǎ	ugutígityǎ	ogotégéterá	ugutígitiryá	'be late'

okorɔ́ga	okorógyá	okorɔ́gɛ́ră	okorógéryá	‘bewitch’
okogɔ́ɔ́gá	okogóógyá	okogɔ́ɔ́gɛ́rá	okogóógéryá	‘slaughter’
okogɔ́ɔ́tá	okogóótyá	okogɔ́ɔ́tɛ́rá	okogóótéryá	‘hold’
ogosɔ́ka	ogosókyá	ogosɔ́kɛ́ră	ogosókéryá	‘poke’
ogotɛ́rɛ́kă	ogotérékyá	ogotɛ́rɛ́kɛrá	ogotérékeryá	‘brew’
okogɛ́sa	okogésyá	okogɛ́sɛ́ră	okogéséryá	‘harvest’
ogosɛ́ɛ́nsá	ogoséénsyá	ogosɛ́ɛ́nsɛ́rá	ogoséénséryá	‘winnow’

to V	*to make to V*	*to V for*	*to make V for*	
ugusííká	ugusííkyá	ogoséékérá	ugusííkíryá	‘to close’
ukurúga	ukurúgyá	okorógéră	ukurúgíryá	‘to cook’
ugusúka	ugusúkyá	ogosókéră	ugusúkíryá	‘to plait’
ukurííngá	ukurííngyá	okoréengérá	ukurííngíryá	‘to fold’
ugusíindá	ugusíindyá	ogoséendérá	ugusíindíryá	‘to win’

imperative	*infinitive*	*they will V*	*then will V for*	
remă	okoréma	mbareréma	mbareréméra	‘cultivate’
bară	okobára	mbarebára	mbarebáréra	‘count’
ată	ogɔɔ́ta	mbarɛɛ́ta	mbarɛɛ́tɛ́ra	‘be split’
ahă	okɔɔ́ha	mbarɛɛ́ha	mbarɛɛ́hɛ́ra	‘pick greens’
agă	okɔɔ́ga	mbarɛɛ́ga	mbarɛɛ́gɛ́ra	‘weed’
aangá	okɔɔ́nga	mbarɛɛ́nga	mbarɛɛ́ngɛ́ra	‘refuse’
andeká	okɔɔ́ndɛ́kă	mbarɛɛ́ndɛ́ka	mbarɛɛ́ndɛ́kɛra	‘write’

imperative	*3s subjunctive*	*3s subjunctive for*	
remă	aremɛ̆	aremerɛ́	‘cultivate’
tɛrɛká	atɛrɛkɛ́	atɛrɛkɛ́rɛ	‘brew’
ebă	ɛɛbɛ̆	ɛɛbɛrɛ́	‘forget’
egă	ɛɛgɛ̆	ɛɛgɛrɛ́	‘learn’
ogă	ɔɔgɛ̆	ɔɔgɛrɛ́	‘be sharp’
ɛyă	ɛɛyɛ̆	ɛɛyɛrɛ́	‘sweep’
ɔrɔká	ɔɔrɔkɛ́	ɔɔrɔkɛ́rɛ	‘come out’

9: Lardil

Account for the phonological alternations seen in the data below.

Bare N	*Accusative*	*Nonfuture*	*Future*	*Gloss*
kentapal	kentapalin	kentapalŋar	kentapaluṛ	dugong
keṯar	keṯarin	keṯarŋar	keṯaruṛ	river
miyaṛ	miyaṛin	miyaṛŋar	miyaṛuṛ	spear
yupur	yupurin	yupurŋar	yupuruṛ	red rock cod
taŋur	taŋurin	taŋurŋar	taŋuruṛ	crab sp.
yaraman	yaramanin	yaramanar	yaramankuṛ	horse

maaṇ	maaṇin	maaṇar	maaṇkuṛ	spear
pirŋen	pirŋenin	pirŋenar	pirŋenkuṛ	woman
mela	melan	melaŋar	melaṛ	sea
ṯawa	ṯawan	ṯawaŋ	ṯawaṛ	rat
wanka	wankan	wankaŋar	wankaṛ	arm
kuŋka	kuŋkan	kuŋkaŋar	kuŋkaṛ	groin
tarŋka	tarŋkan	tarŋkaŋar	tarŋkaṛ	barracuda
ŋuka	ŋukun	ŋukuŋar	ŋukuṛ	water
ŋuṛa	ŋuṛun	ŋuṛuŋar	ŋuṛuṛ	forehead
kaṭa	kaṭun	kaṭuŋar	kaṭuṛ	child
muṇa	muṇun	muṇuŋar	muṇuṛ	elbow
ŋawa	ŋawun	ŋawuŋar	ŋawuṛ	wife
keṇṭe	keṇṭin	keṇṭiŋar	keṇṭiwuṛ	wife
t^{y}impe	t^{y}impin	t^{y}impiŋar	t^{y}impiwuṛ	tail
ŋiṇe	ŋiṇin	ŋiṇiŋar	ŋiṇiwuṛ	skin
pape	papin	papiŋar	papiwuṛ	father's mother
t^{y}empe	t^{y}empen	t^{y}empeŋar	t^{y}empeṛ	mother's father
wiṭe	wiṭen	wiṭeŋar	wiṭeṛ	interior
waŋal	waŋalkin	waŋalkar	waŋalkuṛ	boomerang
men^{y}el	men^{y}elkin	men^{y}elkar	men^{y}elkuṛ	dogfish sp.
makar	makarkin	makarkar	makarkuṛ	anthill
yalul	yalulun	yaluluŋar	yaluluṛ	flame
mayar	mayaran	mayaraŋar	mayaraṛ	rainbow
ṯalkur	ṯalkuran	ṯalkuraŋar	ṯalkuraṛ	kookaburra
wiwal	wiwalan	wiwalaŋar	wiwalaṛ	bush mango
karikar	karikarin	karikariŋar	karikariwuṛ	butter-fish
yiliyil	yiliyilin	yiliyiliŋar	yiliyiliwuṛ	oyster sp
yukar	yukarpan	yukarpaŋar	yukarpaṛ	husband
pulŋar	pulŋarpa	pulŋarpaŋar	pulŋarpaṛ	huge
wulun	wulunkan	wulunkaŋar	wulunkaṛ	fruit sp.
wuṭal	wuṭalt^{y}in	wuṭalt^{y}iŋar	wuṭalt^{y}iwur	meat
kantukan	kantukantun	kantukantuŋar	kantukantuṛ	red
karwakar	karwakarwan	karwakarwaŋar	karwakarwaṛ	wattle sp.
ṯurara	ṯuraraŋin	ṯuraraŋar	ṯuraraŋkuṛ	shark
ŋalu	ŋalukin	ŋalukar	ŋalukuṛ	story
kurka	kurkaŋin	kurkaŋar	kurkaŋkuṛ	pandja
taŋku	taŋkuŋin	taŋkuŋar	taŋkuŋkuṛ	oyster sp.
kurpuṛu	kurpuṛuŋin	kurpuṛuŋar	kurpuṛuŋkuṛ	lancewood
putu	putukan	putukaŋar	putukaṛ	short
maali	maaliyan	maaliyaŋar	maaliyaṛ	swamp turtle
t^{y}iṇtirpu	t^{y}iṇtirpuwan	t^{y}iṇtirpuwaŋar	t^{y}iṇtirpuwaṛ	willie wagtail
pukat^{y}i	pukat^{y}iyan	pukat^{y}iyaŋar	pukat^{y}iyaṛ	hawk sp.
murkuni	murkuniman	murkunimaŋar	murkunimaṛ	nullah

ŋawuŋa	ŋawuŋawun	ŋawuŋawuŋar	ŋawuŋawuṛ	termite
tipiti	tipitipin	tipitipiŋar	tipitipiwuṛ	rock-cod sp.
ṭapu	ṭaput^{y}in	ṭaput^{y}iŋar	ṭaput^{y}iwuṛ	older brother
muŋkumu	muŋkumuŋkun	muŋkumuŋkuŋar	muŋkumuŋkuṛ	wooden axe
t^{y}umput^{y}u	t^{y}umput^{y}umpun	t^{y}umput^{y}umpuŋar	t^{y}umput^{y}umpuṛ	dragonfly

10: Sakha (Yakut)

Give a phonological analysis to the following case-marking paradigms of nouns in Sakha.

noun	*plural*	*associative*	*gloss*
aγa	aγalar	aγalɨin	father
paarta	paartalar	paartalɨin	school desk
tɨa	tɨalar	tɨalɨin	forest
kinige	kinigeler	kinigeliin	book
ǰie	ǰieler	ǰieliin	house
iye	iyeler	iyeliin	mother
kini	kiniler	kiniliin	3rd person
bie	bieler	bieliin	mare
oγo	oγolor	oγoluun	child
χopto	χoptolor	χoptoluun	gull
börö	börölör	börölüün	wolf
tɨal	tɨallar	tɨallɨin	wind
ɨal	ɨallar	ɨallɨin	neighbor
kuul	kuullar	kuulluun	sack
at	attar	attɨin	horse
balɨk	balɨktar	balɨktɨin	fish
ɨskaap	ɨskaaptar	ɨskaaptɨin	cabinet
oγus	oγustar	oγustuun	bull
kus	kustar	kustuun	duck
tünnük	tünnükter	tünnüktüün	window
sep	septer	septiin	tool
et	etter	ettiin	meat
örüs	örüster	örüstüün	river
tiis	tiister	tiistiin	tooth
soroχ	soroχtor	soroχtuun	some person
oχ	oχtor	oχtuun	arrow
oloppos	oloppostor	oloppostuun	chair
ötöχ	ötöχtör	ötöχtüün	abandoned farm
ubay	ubaydar	ubaydɨin	elder brother
saray	saraydar	saraydɨin	barn
tɨy	tɨydar	tɨydɨin	foal
atɨir	atɨirdar	atɨirdɨin	stallion

oyuur	oyuurdar	oyuurduun	forest
üčügey	üčügeyder	üčügeydiin	good person
ĕjiiy	ĕjiiyder	ĕjiiydiin	elder sister
tomtor	tomtordor	tomtorduun	knob
moγotoy	moγotoydor	moγotoyduun	chipmunk
kötör	kötördör	kötördüün	bird
bölköy	bölköydör	bölköydüün	islet
χatɨŋ	χatɨŋnar	χatɨŋnɨin	birch
an	aannar	aannɨin	door
tiiŋ	tiiŋner	tiiŋniin	squirrel
sordoŋ	sordoŋnor	sordoŋnuun	pike
olom	olomnor	olomnuun	ford
oron	oronnor	oronnuun	bed
bödöŋ	bödöŋnör	bödöŋnüün	strong one

noun	*partitive*	*comparative*	*ablative*	*gloss*
aγa	aγata	aγataaγar	aγattan	father
paarta	paartata	paartataaγar	paartattan	school desk
tɨa	tɨata	tɨataaγar	tɨattan	forest
kinige	kinigete	kinigeteeγer	kinigetten	book
ǰie	ǰiete	ǰieteeγer	ǰietten	house
iye	iyete	iyeteeγer	iyetten	mother
kini	kinite	kiniteeγer	kinitten	3rd person
bie	biete	bieteeγer	bietten	mare
oγo	oγoto	oγotooγor	oγotton	child
χopto	χoptoto	χoptotooγor	χoptotton	gull
börö	börötö	börötööγör	böröttön	wolf
tɨal	tɨalla	tɨallaaγar	tɨaltan	wind
ɨal	ɨalla	ɨallaaγar	ɨaltan	neighbor
kuul	kuulla	kuullaaγar	kuultan	sack
moχsoγol	moχsoγollo	moχsoγollooγor	moχsoγolton	falcon
at	atta	attaaγar	attan	horse
balɨk	balɨkta	balɨktaaγar	balɨktan	fish
ɨskaap	ɨskaapta	ɨskaaptaaγar	ɨskaaptan	cabinet
oγus	oγusta	oγustaaγar	oγustan	bull
kus	kusta	kustaaγar	kustan	duck
tünnük	tünnükte	tünnükteeγer	tünnükten	window
sep	septe	septeeγer	septen	tool
et	ette	etteeγer	etten	meat
örüs	örüste	örüsteeγer	örüsten	river
tiis	tiiste	tiisteeγer	tiisten	tooth
soroχ	soroχto	soroχtooγor	soroχton	some person
ötöχ	ötöχtö	ötöχtööγör	ötöχtön	abandoned farm

ubay	ubayda	ubaydaaγar	ubaytan	elder brother
saray	sarayda	saraydaaγar	saraytan	barn
tɨy	tɨyda	tɨydaaγar	tɨytan	foal
atɨɨr	atɨɨrda	atɨɨrdaaγar	atɨɨrtan	stallion
χirur	χirurda	χirurdaaγar	χirurtan	surgeon
üčügey	üčügeyde	üčügeydeeγer	üčügeyten	good person
tomtor	tomtordo	tomtordooγor	tomtorton	knob
moγotoy	moγotoydo	moγotoydooγor	moγotoyton	chipmunk
kötör	kötördö	kötördööγör	kötörtön	bird
suorγan	suorγanna	suorγannaaγar	suorγantan	blanket
χatɨŋ	χatɨŋna	χatɨŋnaaγar	χatɨŋtan	birch
aan	aanna	aannaaγar	aantan	door
tiiŋ	tiiŋna	tiiŋnaaγar	tiiŋtan	squirrel
sordoŋ	sordoŋno	sordoŋnooγor	sordoŋton	pike
olom	olomno	olomnooγor	olomton	ford
bödöŋ	bödöŋnö	bödöŋnööγör	bödöŋtön	strong one

noun	*dative*	*accusative*	*gloss*
aγa	aγaγa	aγanɨ	father
ǰie	ǰieγe	ǰieni	house
iye	iyeγe	iyeni	mother
oγo	oγoγo	oγonu	child
börö	böröγö	börönü	wolf
tɨal	tɨalga	tɨalɨ	wind
kuul	kuulga	kuulu	sack
at	akka	atɨ	horse
balɨk	balɨkka	balɨgɨ	fish
ɨskaap	ɨskaapka	ɨskaabɨ	cabinet
oγus	oγuska	oγuhu	bull
kus	kuska	kuhu	duck
sep	sepke	sebi	tool
et	ekke	eti	meat
tiis	tiiske	tiihi	tooth
ot	okko	otu	grass
soroχ	soroχχo	soroγu	some person
ötöχ	ötöχχö	ötöγü	abandoned farm
oχ	oχχo	oγu	arrow
saray	sarayga	sarayɨ	barn
tɨy	tɨyga	tɨyɨ	foal
kötör	kötörgö	kötörü	bird
oyuun	oyuuŋŋa	oyuunu	shaman
χatɨŋ	χatɨŋŋa	χatɨŋɨ	birch

aan	aaŋŋa	aanɨ	door
olom	olomŋo	olomu	ford

noun	*ourN*	*gloss*	*noun*	*our N*	*gloss*
aγa	aγabɨt	father	iye	iyebit	mother
uol	uolbut	son	kötör	kötörbüt	bird
kɨlaas	kɨlaaspɨt	classroom	ɨskaap	ɨskaappɨt	cabinet
kuorat	kuorappɨt	town	tiis	tiispit	tooth
ohoχ	ohoχput	stove	tünnük	tünnükpüt	window
aan	aammɨt	door	kapitan	kapitammɨt	capitain
tiiŋ	tiiŋmit	squirrel	oron	orommut	bed
kün	kümmüt	day			

11: Sadžava Ukrainian

Give a phonological analysis of the following data. Assume that all surface occurrences of k^y and g^y in this language are derived by rule. Also assume that stress is located on the proper vowel in the underlying representation: the rules for shifting stress are too complex to be considered here. For nouns in declensions II and III, there is a rule that depalatalizes a consonant before the locative and genitive suffixes, respectively. The variation in the locative sg. suffix in declension I (-*i* versus -*u*) is lexically governed: do not write rules which select between these suffixes. Concentrate on extablishing the correct underlying representations for the noun stem.

Declension I

Nom. sg.	*Gen. sg.*	*Loc. sg.*	*Gloss*
plást	plastá	plas^{y}k^{y}í	layer
skorúx	skoruxá	skorus^{y}í	mountain ash
γ^{y}r^{y}íx	γ^{y}r^{y}ixá	γ^{y}r^{y}is^{y}í	sin
pastúx	pastuxá	pastus^{y}í	herdsman
m^{y}n^{y}úx	m^{y}n^{y}úxa	m^{y}n^{y}ús^{y}i	fish sp.
plúγ	plúγa	plúz^{y}i	plow
s^{y}t^{y}íγ	stóγa	stóz^{y}i	stack
sák	sáka	sát^{sy}i	fishnet
bék	bəká	bət^{sy}í	bull
lést	ləstá	ləs^{y}k^{y}í	letter
lést	lésta	lés^{y}k^{y}i	leaf
p^{y}l^{y}ít	plóta	plók^{y}i	wicker fence
s^{y}m^{y}r^{y}íd	smróda	smróg^{y}i	stench
f^{y}íst	fostá	fos^{y}k^{y}í	tail
m^{y}íst	mósta	mós^{y}k^{y}i	bridge
l^{y}íd	lǽdu	lədú	ice
d^{y}r^{y}ít	dróta	drók^{y}i	thick wire

m^{y}ís	mǽdu	mədú	honey
v^{y}íl	volá	vol^{y}í	ox
v^{y}íz	vóza	vóz^{y}i	cart
sér	séra	sér^{y}i	cottage cheese
s^{y}n^{y}íp	snopá	snop^{y}í	sheaf
γréb	γrəbá	γrəb^{y}í	mushroom
lǽb^{y}id	lǽbəda	lǽbəg^{y}i	swan
bǽr^{y}iγ	bǽrəγa	bǽrəz^{y}i	shore
pər^{y}íγ	pəróγa	pəróz^{y}i	dumpling
por^{y}íγ	poróγa	poróz^{y}i	threshhold
bol^{y}ék	bol^{y}əká	bol^{y}ət^{sy}í	abcess
vór^{y}iγ	vóroγa	vóroz^{y}i	enemy
kónək	kónəka	kónət^{sy}i	grasshopper
pót^{y}ik	potóka	potót^{sy}i	stream
t^{y}ík	tóka	tót^{sy}i	current
k^{y}íl	*kolá	*kol^{y}í	stake

Declension II

Nom. sg.	*Gen. sg.*	*Loc. sg.*	*Gloss*
kovál^{y}	koval^{y}é	kovalé	blacksmith
ǰm^{y}íl^{y}	ǰm^{y}il^{y}é	ǰm^{y}ilé	bumblebee
k^{y}r^{y}íl^{y}	k^{y}r^{y}il^{y}é	k^{y}r^{y}ilé	rabbit
učétəl^{y}	učétəl^{y}ə	učétələ	teacher
grǽb^{y}in^{y}	grǽbən^{y}ə	grǽbənə	comb
ólən^{y}	ólən^{y}ə	ólənə	deer
yač^{y}m^{y}ín^{y}	yačmǽn^{y}ə	yačmǽnə	barley
yás^{y}in^{y}	yásən^{y}ə	yásənə	ash tree
z^{y}ék^{y}	z^{y}ék^{y}ə	z^{y}étə	son-in-law

Declension III

Nom. sg.	*Gen. sg.*	*Gloss*
más^{y}k^{y}	mástə	fat
smǽr^{y}k^{y}	smǽrtə	death
v^{y}ís^{y}k^{y}	v^{y}ístə	news
rág^{y}is^{y}k^{y}	rádostə	joy
s^{y}íl^{y}	sólə	salt
póš^{y}is^{y}k^{y}	póšəstə	epidemic
zám^{y}ik^{y}	zámətə	snowstorm
skátər^{y}k^{y}	skátərtə	tablecloth
k^{y}ís^{y}k^{y}	kóstə	bone

12: Koromfe

Vowels in Koromfe come in two varieties, [-ATR] ɩʊɛɔa and [+ATR] iueoʌ. Provide an analysis of the phonological alternations exhibited by the following data, which involve singular and plural forms of nouns and different tense-inflections for verbs.

Singular	*Plural*	*gloss*
gɩbrɛ	gɩba	hatchet
hubre	hubʌ	ditch
nɛbrɛ	nɛba	pea
lugre	lugʌ	side
dĩŋgre	dĩŋgʌ	bush type
zoŋgre	zongʌ	wing
lɔ̃ŋgrɛ	lɔ̃ŋga	shoe
hullre	hullʌ	gutter
sɛkrɛ	sɛka	half
tɛfrɛ	tɛfa	cotton fiber
dabɛɛrɛ	dabɛɛya	camp
dɔɔrɛ	dɔɔya	long
gɩgaarɛ	gɩgaaya	vulture
pʊpaarɛ	pʊpaaya	grass type
koire	koyʌ	bracelet
dʊmdɛ	dʊma	lion
hulomde	hulomʌ	marrow
tɛmdɛ	tɛma	beard
logomde	logomʌ	camel
bɩndɛ	bɩna	heart
bɔ̃ndɛ	bɔ̃na	hoe
honde	hondʌ	bean
geŋde	geŋʌ	pebble
zɛŋdɛ	zɛŋa	upper arm
bɛllɛ	bɛla	back
dɔllɛ	dɔla	hill
yɩllɛ	yɩla	horn
selle	selʌ	space
pallɛ	pala	stretcher
deŋgele	deŋgelʌ	open area
sembele	sembelʌ	piece
dãĩnɛ	dãỹã	wood
hʊ̃ĩnɛ	hʊ̃ỹã	caterpillar
kɔ̃ĩnɛ	kɔ̃ỹã	squirrel
kɔ̃ɔ̃nɛ	kɔ̃ɔ̃ỹã	old
sɔ̃ɔ̃nɛ	sɔ̃ɔ̃ỹã	period

bɛtɛ	bɛra	male animal
datɛ	dara	chest
gete	gerʌ	forked stick
gote	gorʌ	stream
bɪtɛ	bɪrɛ	frog
dɔtɛ	dɔra	cloud

unmarked	*past*	*progressive*	*gloss*
ta	taɛ	taraa	shoot
gɔ	gɔɛ	gɔraa	go back
kʊ	kɔɛ	kʊraa	kill
tu	toe	turʌʌ	coat
li	lee	lirʌʌ	forget
dɪ	dɛ	dɪraa	eat
tã	tãẽ	tãnaa	contradict
nẽ	nẽ	nẽnaa	defecate
saɪ	sayɛ	saɪraa	separate
yɛɪ	yɛyɛ	yɛɪraa	waste
sɔɪ	sɔyɛ	sɔɪraa	split
ỹɛ̃ĩ	ỹɛ̃ỹɛ̃	ỹɛ̃ĩnaa	catch
dɔ̃ĩ	dɔ̃ỹɛ̃	dɔ̃ĩnaa	dream
kɛndɪ	kɛndɛ	kɛndraa	finish
kɛ̃sɪ	kɛ̃sɛ	kɛ̃sraa	surpass
kɛtɪ	kɛtɛ	kɛtraa	open
tɛŋgɪ	tɛŋgɛ	tɛŋgraa	accompany
yisi	yise	yisrʌʌ	suffice
yɪsɪ	yɪsɛ	yɪsraa	draw water
birgi	birge	birgrʌʌ	blacken
pasgɪ	pasgɛ	pasgraa	split
mɛntɪ	mɛntɛ	mɛntraa	assemble
gondu	gonde	gondrʌʌ	depart
hɔ̃ŋgʊ	hɔ̃ŋgɛ	hɔ̃ŋgraa	point
sʊrgʊ	sʊrgɛ	sʊrgraa	drop
hɔ̃kʊ	hɔ̃kɛ	hɔ̃kraa	scratch
zullu	zulle	zullrʌʌ	bow
sɪbʊ	sɪbɛ	sɪbraa	die
zambʊ	zambɛ	zambraa	deceive
wufu	wufe	wufrʌʌ	borrow
zɪgamsʊ	zɪgamsɛ	zɪgamsraa	be dirty
hẽmsʊ	hẽmsɛ	hẽmsraa	meet
leli	lele	lellʌʌ	sing
pɪlɪ	pɪlɛ	pɪllaa	trample flat
tarɪ	tarɛ	tataa	plaster

fɛrɩ	fɛrɛ	fɛtaa	cultivate
tʊrʊ	tʊrɛ	tʊtaa	introduce

Advanced topics and readings

Aspects of the methodology of problem solving in phonology are discussed in Kenstowicz & Kisseberth 1979, especially chapter 5, as well as Zwicky 1973, 1974, 1975 and Pullum 1976. There are numerous publications which give extended analyses of the phonology of a particular language, and it would be impossible to even give a representative sample. Some suggestions for extended descriptions of languages include the following: Arabic (Brame 1970: Classical Arabic; Al-Mozainy 1981, Irshied 1984: Modern dialects), Basque (Hualde 1991), Biblical Hebrew (Prince 1976, Malone 1993), Chimwini (Kisseberth & Abasheikh 1975, 1976a,b), Choctaw (Ulrich 1986), Hungarian (Vago 1980, Siptár & Törkenczy 2000), Javanese (Dudas 1976), Jita (Downing 1996), Kashaya (Buckley1994), Kimatuumbi (Odden 1996), Klamath (White 1973), Lithuanian (Kenstowicz 1972), Luganda (Clements 1986, Hyman & Katamba 1990, 1992, 1993), Luyia (Dalgish 1976), Makua (Cheng & Kisseberth 1979, 1980, 1981, 1982), Odawa (Piggott 1980), Slovak (Rubach 1993).

8

Phonological Typology and Naturalness

One of the main goals of many phonologist is to explain why certain phonological patterns are found in many languages, while other patterns are found in few or no languages. This chater looks at the phonological typology — the study of common vs. common, natural vs. unnatural phonological rules, and looks at some of these commonly occurring phonological properties.

A very widely invoked criterion in deciding between one analysis of the phonology of a language versus some other analysis is whether the rules of one analysis are more natural, usually judged by determining whether the rule in question occurs more often across languages. As a prerequisite to explaining *why* some processes are common, uncommon, or even unattested, you need an idea of *what* these common patterns are, and providing this information is the domain of **typology**. While only a very small fraction of the roughly 7,000 languages spoken in the world have been studied in a way that yields useful information for phonological typology, crosslinguistic studies have revealed many recurrent patterns, which form the basis for theorizing about the basis for these patterns.

1. Inventories

One area where a comparative, typological approach is often employed is in the study of phonological segment inventories. It has been observed that certain kinds of segments occur in very many languages, while others occur in only a few. This observation is embodied in the study of **markedness**, which is the idea that not all segments or sets of segments have equal status in phonological systems. For example, many languages have the stop consonants [p t k], which are said to be unmarked, but relatively few have the uvular [q], which is said to be marked. Markedness is a comparative concept, so [q] is more marked that [k] but less marked than [ʕ]. Many languages have the voiced approximant [l], but few have the voiceless lateral fricative [ɬ] and even fewer have the voiced lateral fricative

[ʒ]. Very many languages have the vowel system [i e a o u]; not many have the vowels [ɯ ɜ ʊ ɪ].

Related to the frequency of types of segments across languages is the concept of an **implicational relation**. An example of an implicational relation is that between oral and nasal vowels. Many languages have only oral vowels (Spanish, German), and many languages that have both oral and nasal vowels (French, Portuguese), but no languages have only nasal vowels; that is, the existence of nasal vowels implies the existence of oral vowels. All languages have voiced sonorant consonants, and some additionally have voiceless sonorants: no language has only voiceless sonorants. Or, many languages have only a voiceless series of obstruents, others have both voiced and voiceless obstruents; but none have only voiced obstruents.

The method of comparing inventories. Three methodological issues need to be considered in conducting such typological studies. First, determing what is more common versus less common requires a good-sized random sample of the languages of the world. However, information on phonological structure is not easily available for many of the languages of the world, and existing documentation tends to favor certain languages (for example the Indo-European languages) over other languages (those of New Guinea).

Second, it is often difficult to determine the true phonetic values of segments in a language which you do not know, so interpreting a symbol in a grammar runs the risk of circularity: the consonants spelled <p t k> may in fact be ejective [p' t' k'], but <p t k> are used in the spelling system because *p, t, k* are "more basic" segments and the author of a grammar may notate ejectives with "more basic" symbols if no plain non-ejective voiceless stops exist in the language. This is the case in many Bantu languages of Southern Africa, such as Gitonga and Zulu, which contrast phonetically voiceless aspirated and ejective stops — there are no plain unaspirated voiceless stops. Therefore, the ejectives are simply written <p t k> because there is no need to distinguish [p] and [p']. This phonetic detail is noted in some grammars, but not in all, and if you do not have experience with the language and do not read a grammar that mentions that <p> is ejective, you might not notice that these languages have no plain voiceless stops.

Third, many typological claims are statistical rather than absolute — they are statements about what happens most often, and therefore encountering a language that does not work that way does not falsify the claim. It is very difficult to refute a claim of the form "X is more common than Y", except if a very detailed numerical study is undertaken.

Typical inventories. With these caveats, here are some general tendencies of phoneme inventories. In the realm of consonantal place of articulation, and using voiceless consonants to represent all obstruents at that place of articulation, the places represented by [p, t, k] are the most basic, occurring in almost all languages

of the world. The next most common place would be alveopalatal; less common are uvulars, dentals and retroflex coronals;[1] least common are pharyngeals. All languages have a series of simple consonants lacking secondary vocalic articulations. The most common secondary articulation is rounding applied to velars, then palatalization; relatively uncommon is rounding of labial consonants; least common would be distinctive velarization or pharyngealisation of consonants. Among consonants with multiple closures, labiovelars like [kp] are the most common; clicks, though rare, seem to be more common that linguolabials.

In terms of manners of consonant articulation, stops are found in all languages. Most language have at least one fricative, and the most common fricative is *s*, followed by *f* and *š*, then *x*, then *θ* and other fricatives. The most common affricates are the alveopalatals, then the other coronal affricates; p^f and k^x are noticeably less frequent. In terms of laryngeal properties of consonants, all languages have voiceless consonants (though in many, the voice onset time of stops is relatively long and the voiceless stops could be considered to be phonetically aspirated). Plain voiced consonants are also common, as is a contrast between voiceless unaspirated and voiceless aspirated stops. Ejectives, implosives and breathy-voiced consonants are much less frequent. Among fricatives, voicing distinctions are not unusual, but aspiration, breathy voicing and ejection are quite marked.

Nearly all languages have at least one nasal consonant, but languages with a rich system of place contrasts among obstruents may frequently have a smaller set of contrasts among nasals. Most languages also have at least one of [r] or [l], and typically have the glides [w y]. Modal voicing is the unmarked case for liquids, nasals and glides, with distinctive laryngealisation or devoicing ~ aspiration being uncommon. Among laryngeal glides, [h] is the most common, then [ʔ], followed by the relatively infrequent [ɦ].

The optimal vowel system would seem to be [i e a o u], and while the mid vowels [e o] are considered to be more marked that the high vowels [i u] for various reasons having to do with the operation of phonological rules (context-free rules raising mid vowels to high are much more common than context free rules lowering high vowels to mid), there are fewer languages with just the vowels [i u a] than with the full set [i u e o a]. The commonness of front rounded and back unrounded vowels is correlated with vowel height, so a number of languages have [ü] and not [ö], but very few have [ö] and not [ü]. Full exploitation of the possibilities for low back and round vowels ([æ œ ɑ ɒ] is quite rare, but it is not hard to find languages with [i ü ɨ u]. As noted earlier, oral vowels are more common than nasal vowels, and modal voiced vowels are more common than creaky voiced or breathy vowels].

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[1] But when a language has only one varieties of coronal, that variety may well be dental or post-alveolar.

2. Segmental processes

We begin our typological survey of processes with segmental processes and procede to prosodic ones. Put roughly, segmental phonology deals with how the features of one segment affect the features of another segment, and prosodic processes are those that pertain to the structure of syllables, stress and the rhythmic structure of words, and phenomena which relate to the position of segments in a phonological string. This division of processes is at this point strictly heuristic, but research has shown that there are important representational difference between segmental i.e. featural representations, and syllabic or rythmic representations — further questions regarding representations are taken up in chapter 11.

2.1. Assimilations

The most common phonological process in language is **assimilation**, where two segments become more alike by having one segment take on values for one or more features from a neighboring segment.

Vowel harmony. An example of assimilation is vowel harmony, and the architypical example of vowel harmony is the front-back vowel harmony process of Turkish. In this language, vowels within a word are (generally) all front, or all back, and any suffixes added to a stem will alternate according to the frontness of the preceding vowel. Thus the genitive suffix which varies between *in* and *ɨn* will surface with a front vowel if the preceding stem ends in a front vowel, and in a back vowel if the preceding vowel is back. The vowel of the plural suffix *lar* ~ *ler* exhibits similar variation.

(1)

nom. sg.	*gen. sg.*	*nom. pl.*	*gen. pl.*	
ip	ip-in	ip-ler	ip-ler-in	"rope"
fil	fil-in	fil-ler	fil-ler-in	"elephant"
iš	iš-in	iš-ler	iš-ler-in	"work"
čikiš	čikiš-in	čikiš-lar	čikiš-lar-in	"exit"
kɨz	kɨz-in	kɨz-lar	kɨz-lar-ɨn	"girl"
yɨl	yɨl-ɨn	yɨl-lar	yɨl-lar-ɨn	"year"
el	el-in	el-ler	el-ler-in	"hand"
ev	ev-in	ev-ler	ev-ler-in	"house"
biber	biber-in	biber-ler	biber-ler-in	"pepper"
bilet	bilet-in	bilet-ler	bilet-ler-in	"ticket"
sap	sap-ɨn	sap-lar	sap-lar-ɨn	"stalk"
adam	adam-ɨn	adam-lar	adam-lar-ɨn	"man"

This process can be stated formally as (2).

(2) $V \rightarrow [\alpha\text{back}] \;/\; \underset{[\alpha\text{back}]}{V} \; C_0 \; \_\_$

A second kind of vowel harmony found in Turkish is rounding harmony. In Turkish, a rule assimilates any high vowel to the roundness of the preceding vowel. Consider the following data, involving stems which end in round vowels.

(3)

nom. sg.	*gen. sg.*	*nom. pl.*	*gen. pl.*	
yüz	yüz-ün	yüz-ler	yüz-ler-in	"face"
pul	pul-un	pul-lar	pul-lar-ɨn	"stamp"
ok	ok-un	ok-lar	ok-lar-ɨn	"arrow"
okul	okul-un	okul-lar	okul-lar-ɨn	"school"
köy	köy-ün	köy-ler	köy-ler-in	"village"
göl	göl-ün	göl-ler	göl-ler-in	"lake"
gün	gün-ün	gün-ler	gün-ler-in	"day"
son	son-un	son-lar	son-lar-ɨn	"end"
afyon	afyon-un	afyon-lar	afyon-lar-ɨn	"opium poppy"

The genitive suffix which has a high vowel becomes rounded when the preceding vowel is round, but the plural suffix which has a non-high vowel does not assimilate in roundness. Thus the data in (3) can be accounted for by the following rule.

(4) $\underset{[+\text{high}]}{V} \rightarrow [\alpha\text{round}] \;/\; \underset{[\alpha\text{round}]}{V} \; C_0 \; \_\_\_\_$

A problem that arises in many vowel harmony systems is that it is difficult if not impossible be certain what the underlying vowel of the suffix is. For the plural suffix, we can surmise that the underlying vowel is non-round, since it is never phonetically round, so the most probably hypotheses are /a/ or /e/. For the genitive suffix, any of /i,ɨ,ü,u/ would be plausible, since from any of these vowels, the correct output will result by applying these rules.

It is sometimes assumed that, if all other factors are the same for selecting between competing hypotheses about the underlying form, a less marked (cross-linguistically frequent) segment should be selected over a more marked segment. By that reasoning, you might narrow the choice to /i,u/ since *ɨ,ü* are significantly more marked that /i,u/. The same reasoning might lead you to specifically conclude that alternating high vowels are /i/, on the assumption that *i* is less marked that *u*: however, that conclusion regarding markedness is not certain. The validity of invoking segmental markedness for chosing underlying forms is a theoretical assumption, and does not have clear empirical support. A further solution to the problem of picking between underlying forms is that [+high] suffix vowels are not specified for backness or roundness, and thus could be represented with the symbol /I/, which is not a actual and pronounceable vowel, but represents a so-called **ar-**

chiphoneme having the properties of being a vowel and being high, but being indeterminate for the properties [round] and [back]. There are a number of theoretical issues which surround the possibility of having partially specified segments, which we will not go into here.

Mongolian also has rounding harmony: in this language, only non-high vowels undergo the assimilation, and only non-high vowels trigger the process.

(5)	*nominative*	*instrumental*	*accusative*	
	de:l	de:l-e:r	de:l-i:g	"coat"
	gal	gal-a:r	gal-i:g	"fire"
	dü:	dü:-ge:r	dü:-g	"younger brother"
	nöxör	nöxör-ö:r	nöxör-i:g	"comrade"
	doro:	doro:-go:r	doro:-g	"stirrup"

This rule can be forumlated as in (6).

(6) $$\begin{matrix} V \rightarrow [\alpha\text{round}] \,/ & V & C_0 & \_\_\_ \\ [\text{-hi}] & \begin{bmatrix} \text{-hi} \\ \alpha\text{rd} \end{bmatrix} & & \end{matrix}$$

Typological research has revealed a considerable range of variation in the conditions that can be put on a rounding harmony rule. In Sakha, high vowels assimilate in roundness to round high and non-high vowels (cf. *aγa-l~~i~~in* "father (assoc.)", *sep-tiin* "tool (assoc.)" vs. *oγo-luun* "child (assoc.)", *börö-lüün* "wolf (assoc.)", *tünnük-tüün* "window (assoc.)"), but non-round vowels only assimilate in roundness to a preceding non-high vowel (cf. *aγa-lar* "fathers", *sep-ter* "tools", *tünnük-ter* "windows", *kus-tar* "ducks" vs. *oγo-lor* "children", *börö-lör* "wolves"). As seen in Chapter 7, in Yokuts, vowels assimilate rounding from a preceding vowel of the same height (thus, high vowels assimilate to high vowels, low vowels assimilate to low vowels). Kirghiz vowels generally assimilate in roundness to any preceding vowel except that a non-high vowels does not assimilate to a back high round vowel (though it will assimilate rounding from a front high round vowel).

(7)	*accusative*	*dative*	*gloss*
	taš-~~ti~~	taš-ka	stone
	iš-ti	iš-ke	job
	uč-tu	uč-ka	tip
	konok-tu	konok-ko	guest
	köz-tü	köz-gö	eye
	üy-tü	üy-gö	house

This raises the question whether, for example, you might find a language where roundness harmony only takes place between vowels of different heights. Al-

though such examples are not known to exist, we must be cautious about inferring too much from that fact, since the vast majority of languages with rounding harmony are members of the Altaic language family (e.g. Mongolian, Kirghiz, Turkish, Sakha). The existence of these kinds of rounding harmony means that phonological theory must provide the tools to describe them: what we do not know is whether other types of rounding harmony, not found in Altaic, also exist. Nor is it safe, given our limited database on variation within rounding harmony systems, to make very strong pronouncements about what constitutes 'common' versus 'rare' patterns of rounding harmony.

Another type of vowel harmony is vowel-height harmony. Such harmony exists in Kuria, where the tense mid vowels *e,o* become *i,u* before a high vowel. Consider (8), illustrating variations in noun prefixes (*omo ~ umu; eme ~ imi; eke ~ ege ~ iki ~ igi; ogo ~ ugu*) conditioned by the vowel to the right.

(8)	omoó-nto	"person"	omo-sááčá	"male"
	omo-té	"tree"	omo-góóndo	"plowed field"
	umu-ríísya	"boy"	umu-múra	"young man"
	eme-té	"trees"	imi-sí	"sugar canes"
	ege-sáka	"stream"	ege-té	"chair"
	egeé-nto	"thing"	igi-túúmbe	"stool"
	iki-rúúŋgúuri	"soft porridge"	iki-múúnɛ́	"deer"
	ogo-gábo	"huge basket"	ogo-tábo	"huge book"
	ogo-sééndáno	"huge needle"	ogo-gɛ́na	"huge stone"
	ugu-síri	"huge rope"		

These examples show that tense mid vowels appear before the low vowel *a* and the tense and lax mid vowels *e, ɛ, o, ɔ*, which are [-high], and high vowels appear before high vowels, so based just on the phonetic environment where each variant appears, we cannot decide what the underlying value of the prefix is, [-high] or [+high]. Additional data shows that the prefixes must underlying contain mid vowels: there are also prefixes which contain invariantly [+high] vowels.

(9)	iri-tɔ́ɔ́kɛ	"banana"	iri-kɛ́ɛ́ndɔ	"date fruit"
	iri-hííndi	"corn cob"	iri-síko	"yard"
	iri-té	"big chair"	iri-tóro	"buttock"
	ibi-góóndo	"small fields"	ibi-gáátɛ	"small breads"
	ibi-gúrúbe	"small pigs"	ibi-sáka	"streams"
	ibi-té	"chairs"	ibií-nto	"things"
	ibi-túúmbe	"stools"	ibi-rúúŋgúuri	"soft porridges"
	iči-séésé	"dog"	iči-ŋáámwi	"cat"
	iči-ŋɔ́ɔ́mbɛ	"cow"	ičii-ŋgúrúbe	"pig"
	iči-tíííñi	"animal"	ičii-ntárɛ	"stones"

Thus the alternations in (8) can be described with the rule (10).

(10) $$\underset{[+\text{tense}]}{V} \rightarrow [+\text{hi}] \;/\; \_\_\_\; C_0 \;\; \underset{[+\text{hi}]}{V}$$

Another variety of vowel height harmony is complete height harmony, an example of which is found in Kimatuumbi. This language distinguishes four phonological vowel heights, examplified by the vowels *a, ɛ, ɪ* and *i*. The vowels of the passive suffix -*ilw*-, the stative suffix -*ik*- and the causative suffix -*iy*- assimilate completely to the height of the preceding non-low vowel *ɛ, ɪ* and *i*.

(11)	ásim-a	"borrow"	ásim-ilw-a	"be borrowed"
	ín-a	"dance"	in-ilw-a	"be danced"
	kún-a	"grate coconut"	kún-ilw-a	"be grated"
	úʊg-a	"bathe"	úʊg-ɪlw-a	"be bathed"
	twíɪk-a	"lift a load"	twíɪk-ɪlw-a	"be lifted"
	bɔ́ɔl-a	"tear bark off a tree"	bɔ́ɔl-ɛlw-a	"be de-barked"
	kɛ́ɛŋgɛɛmb-a	"uproot tubers"	kɛ́ɛŋgɛɛmb-ɛlw-a	"be uprooted"
	út-a	"pull"	út-ik-a	"be pullable"
	búundal-a	"be blunt"	búndal-ik-a	"be bluntable"
	kʊ́ʊl-a	"pull teeth"	kʊ́ʊl-ɪk-a	"be pulled"
	kɛ́t-a	"cut up"	kɛ́t-ɛk-a	"be cut up"
	čáag-a	"grind"	čáag-iy-a	"make grind"
	číinj-a	"slaughter"	číinj-iy-a	"make slaughter"
	úʊg-a	"bathe"	úʊg-ɪy-a	"make bathe"
	bɔ́ɔl-a	"de-bark"	bɔ́ɔl-ɛy-a	"make de-bark"
	čɛ́ɛŋg-a	"build"	čɛ́ɛŋg-ɛy-a	"make build"

This process involves the complete assimilation of suffix vowels to the values of [hi] and [tense] (or [ATR]) from the preceding non-low vowel. Since the low vowel *a* does not trigger assimilation, the context after *a* reveals the underlying nature of harmonizing vowels, which we can see are high and tense. The following rule will account for the harmonic alternations in (11).

(12) $$\begin{bmatrix} V \\ -\text{low} \end{bmatrix} \rightarrow \begin{bmatrix} \alpha\text{hi} \\ \beta\text{tense} \end{bmatrix} / \begin{bmatrix} -\text{low} \\ \alpha\text{hi} \\ \beta\text{tense} \end{bmatrix} C_0 \_\_\_$$

Akan exemplifies a type of vowel harmony which is common especially among the languages of Africa, which is assimilation of the feature ATR. In Akan, vowels within the word all agree in their value for [ATR]. In (13a) the prefix

vowels are [+ATR] before the [+ATR] vowel of "eat" and [-ATR] before the [-ATR] vowel of "be called"; (13b) shows this same harmony affecteing other tense-aspect prefixes.

(13) a.

	"eat"	"be called"
1s	mi-di	mɪ-dɪ
2s	wu-di	wʊ-dɪ
3s	o-di	ɔ-dɪ
1p	ye-di	yɛ-dɪ
2p	mu-di	mʊ-dɪ
3p	wo-di	wɔ-dɪ

b.

o-be-di	"he will eat"	ɔ-bɛ-dɪ	"he'll be called"
o-di-i	"he ate"	ɔ-dɪ-ɪ	"he was called"
o-ko-di	"he goes and eats"	ɔ-kɔ-dɪ	"he goes and is called"

Vowel nasalization is also a common assimilatory process affecting vowels, and can be seen in the data of (14) from Gã. These data illlustrate nasalization affecting the plural suffix, which is underlyingly /i/ and assimilates nasality from the immediately preceding vowel.

(14)

mlɛɛbo	mlɛɛbo-i	"liver"
nãne	nãne-i	"leg"
wu	wu-i	"bone"
čĩisi	čĩisi-i	"plate"
akplɔ	akplɔ-i	"spear"
akwadu	akwadu-i	"banana"
gbɛ	gbɛ-i	"path"
mĩ	mĩ-ĩ	"drum"
sɛ̃	sɛ̃-ĩ	"throat"
mũsũ	mũsũ-ĩ	"stomach"
tũ	tũ-ĩ	"gun"
ŋmɔ̃	ŋmɔ̃-ĩ	"farm"
gãgã	gãgã-ĩ	"bee"
lemã	lemã-ĩ	"ax"
gɔ̃	gɔ̃-ĩ	"hill"

Another kind of vowel harmony, one affecting multiple features, is sometimes termed 'place harmony', an example of which comes from Efik. In Efik, the prefix vowel /ɛ/ becomes [a] before [a], [ɔ] before [ɔ], [ɛ] before [ɛ], [e] before [e] and [i], and [o] before [o] and [u].

(15)	*3sg*	*3pl*	
	e-di	e-di	'come'
	ɛ-bɛri	e-bɛri	'shut'
	a-kaŋ	e-kaŋ	'deny'
	ɔ-bɔ	e-bɔ	'take'
	o-kop	e-kop	'hear'
	o-kut	e-kut	'see'

This process involves assimilation of all features from the following vowel, except the feature [high].

(16) $$\varepsilon \rightarrow \begin{bmatrix} \alpha\text{round} \\ \beta\text{tense} \\ \gamma\text{back} \end{bmatrix} / \_\_\_ C_0 \begin{bmatrix} \text{V} \\ \alpha\text{round} \\ \beta\text{tense} \\ \gamma\text{back} \end{bmatrix}$$

Finally, complete vowel harmony, where one vowel takes on all features from a neighboring vowel, is found in some languages such as Kolami. This language has a rule of vowel epenthesis which breaks up final consonant clusters and medial clusters of more than two consonants. The inserted vowel harmonizes with the preceding vowel.

(17)	*stem*	*1s pres*	*1s past*	*imperative*	
	/tum/	tum-atun	tum-tan	tum	'sneeze'
	/agul/	agul-atun	agul-tan	agul	'dig'
	/dakap/	dakap-atun	dakap-tan	dakap	'push'
	/katk/	katk-atun	katak-tan	katak	'strike'
	/melg/	melg-atun	meleg-tan	meleg	'shake'
	/kink/	kink-atun	kinik-tan	kinik	'break'

Another example of complete vowel harmony is seen in the following examples of the causative prefix of Klamath, whose vowel completely assimilates to the following vowel.

(18)		
	sna-batgal	"gets someone up from bed"
	sne-l'e:ml'ema	"makes someone dizzy"
	sno-bo:stgi	"causes something to turn black"
	sni-nklilk'a	"makes dusty"

Complete harmony is unlikely to ever be completely general — all of these examples are restricted in application to specific contexts, such as epenthetic vowels as in Kolami, or vowels of specific affixal morphemes as in Klamath. Another con-

text where total harmony is common is between vowels separated only by laryngeal glides *h* and *ʔ*, a phenomenon referred to as **translaryngeal harmony**, as illustrated in Nenets by the alternation in the locative forms *to-hona* "lake", *pi-hina* "street", *pʸa-hana* "tree", *pe-hena* "stone", *tu-huna* "fire". The consequences of a completely unrestricted vowel harmony would be rather drastic — any word could only have one kind of vowel in it, were such a rule to be totally general.

Consonant assimilations. One of the most common processes affecting consonants is the assimilation of a nasal to the place of articulation of a following consonant. An example of this process comes from Kimatuumbi, seen in (19), where the plural prefix /ñ/ takes on the place of assimilation of the following consonant.

(19)	*Singular*	*Plural*	
	lwɩ́mo	ñímo	"land being weeded"
	lwaámbo	ñaámbo	"bead"
	lweémbe	ñeémbe	"shaving knife"
	lugói	ŋgói	"rope"
	lugolóká	ŋgolóká	"straight"
	lubáu	mbáu	"rib"
	lubágalo	mbagálo	"lath"
	luǰiíŋgyá	ñǰiíŋgyá	"entered"
	lulaála	ndaála	"pepper"
	lulímí	ndími	"tongue"
	lupaláaí	mbaláaí	"bald head"
	lupaálá	mbaálá	"wanted"
	lutéelá	ndeelá	"piece of wood"
	lučeéñǰemá	ñǰeéñǰemá	"mosquito"
	lučwiíčwi	ñǰwiíčwi	"tomato"
	lukíligo	ŋgilígo	"place for initiates"
	lukíli	ŋgíli	"palm"

Place assimilation of nasals in Kimatuumbi affects all nasals, so the data in (20a) illustrate assimilation of preconsonantal /n/ resulting from an optional vowel deletion rule, and (20b) illustrates assimilation of /m/.

(20)				
	a.	ni-bálaaŋgite	m-bálaaŋgite	"I counted"
		ni-ǰíiŋgiile	ñ-ǰíiŋgiile	"I entered"
		ni-góoñǰite	ŋ-góoñǰite	"I slept"
	b.	mu-páalite	m-páalite	"you (pl.) wanted"
		mu-téliike	n-téliike	"you (pl.) cooked"
		mu-čáawiile	ñ-čáawiile	"you (pl.) ground"
		mu-káatite	ŋ-káatite	"you (pl.) cut"

Sometimes, a language with place assimilation of nasals will restrict the process to a specific place of articulation nasals. For instance, Chukchi assimilates *ŋ* to a following consonant, but does not assimilate *n* or *m*. Thus the stem *teŋ* "good" retains underlying *ŋ* before a vowel, and otherwise assimilates to the following consonant: however, as the last two examples show, *n* and *m* do not assimilate to a following consonant.

(21)	teŋ-əɬʔ-ən	"good"
	tam-waɣərɣ-ən	"good life"
	tam-pera-k	"to look good"
	tan-čotčot	"good pillow"
	tan-ɬəmŋəɬ	"good story"
	tan-rʔarqə	"good breastband"
	nə-mkə-kin	"often"
	ɣa-n-pera-w-ɬen	"decorated"

A common assimilation affecting consonants after nasals is postvocalic voicing, illustrated with by Kimatuumbi in (22). The data in (22a) illustrates voicing of an underlyingly voiceless consonant at the beginning of a stem after the prefix *ñ*. The data in (22b) show voicing of a consonant in a verb after the reduced form of the subject prefix *nị*.[2] Here, the vowel /ị/ in the prefix optionally deletes, and when it does, it causes a change in the voicing of an initial stop.

(22)	a.	*Singular*	*Plural*	
		lu-paláaí	m-baláaí	"bald head"
		lu-čwiíčwi	ñ-ǰwiíčwi	"tomato plant"
		lu-téelá	n-deelá	"piece of wood"
		lu-kíligo	ŋ-gilígo	"initiate's place"
		lu-tiníká	n-diníká	"cut"
		lu-temá.á	n-demá.á	"chopped"
		lu-čapíičá	ñ-ǰapíičá	"clean"
	b.	*1s. past*	*optional pronunciation*	
		ni-páalite	m-báalite	"I wanted (recent)"
		ni-téliike	n-déliike	"I cooked (recent)"
		ni-čónite	ñ-ǰónite	"I sewed (recent)"
		ni-kúbiile	ŋ-gúbiile	"I hit on legs (recent)"

[2] Not all preconsonantal nasals condition this voicing process in Kimatuumbi; only nasals which are non-syllabic in the intermediate representation do. Hence [mp] sequences, such as found in (20), are possible, since the process that deletes the vowel *u* results in a syllabic nasal in the intermediate representation — see Odden 1996 for discussion.

Stop consonants frequently nasalize before nasal consonants, and an example of this process is found in Korean. The examples in (23a) are stems with final nasal consonants; those in (23b) have oral consonants, revealed before the infinitive suffix *a* ~ *ə*, and undergo nasalization of that consonant before the past tense suffix *-ɨ̃nta*.

(23)		*Infinitive*	*Past*	
	a.	an-a	an-ɨ̃nta	"hug"
		sin-ə	sin-ɨ̃nta	"wear shoes"
		t'aɨ̃m-ə	t'aɨ̃m-ɨ̃nta	"trim"
		kam-a	kam-ɨ̃nta	"wind"
		nəm-ə	nəm-ɨ̃nta	"overflow"
		nam-a	nam-ɨ̃nta	"remain"
		$č^h$am-a	$č^h$am-ɨ̃nta	"endure"
	b.	ip-ə	im-ɨ̃nta	"wear"
		kup-ə	kum-ɨ̃nta	"bend"
		čəp-ə	čəm-ɨ̃nta	"fold"
		tat-ə	tan-ɨ̃nta	"close"
		put^h-ə	pun-ɨ̃nta	"adhere"
		$čoč^h$-a	čon-ɨ̃nta	"follow"
		mək-ə	məŋ-ɨ̃nta	"eat"
		tak'-a	taŋ-ɨ̃nta	"polish"
		čuk-ə	čuŋ-ɨ̃nta	"die"
		ik-ə	iŋ-ɨ̃nta	"ripen"

Kimatuumbi presents the mirror-image process, of post-nasal nasalization (this process is only triggered by nasals which are moraic in the intermediate representation). On the left in (24a), the underlying consonant is revealed when a vowel-final prefix noun class prefix stands before the stem, and on the right a nasal prefix stands before the stem, causing the initial consonant to become nasalized. In (24b), nasalization applies to the example in the second column, which undergoes an optional rule deleting the vowel *ṵ* from the prefix /mṵ/.

(24)	a.	a-baánda	"slaves"	m-maánda	"slave"
		a-láalo	"fools"	n-náalo	"fool"
		a-gúndumúyi	"scarers"	ŋ-ŋúndumúyi	"scarer"
		mi-butúka	"cars"	m-mutúka	"car"
		mi-dálaánzi	"bitter oranges"	n-nálaánzi	"bitter orange"
		mi-lipú	"trees (sp.)"	n-nipú	"tree (sp.)"
		mi-gúunda	"fields"	ŋ-ŋúunda	"field"

b.	mu-buundíke	m-muundíke	"you should store"
	mu-laabúke	n-naabúke	"you should breakfast"
	mu-jiiŋgí	ñ-ñiiŋgí	"you should enter"

Many languages have a process of voicing assimilation, especially in clusters of obstruents which must agree in voicing. Most often, obstruents assimilate regressively to the last obstruent in the cluster. For example, in Sanskrit a stem final consonant reveals its underlying voicing when the following affix begins with a sonorant, but assimilates in voicing to a following obstruent.

(25)	kr̥ṇṭ-mas	b^{h}ind-mas	1pl indicative active
	kr̥ṇṭ-e	b^{h}ind-e	1sg indicative middle
	kr̥ṇṭ-ṭ^{h}a	b^{h}int-t^{h}a	2pl indicative active
	kr̥ṇṭ-ṭe	b^{h}int-te	3sg indicative middle
	kr̥ṇḍ-ḍ^{h}ve	b^{h}ind-d^{h}ve	2pl indicative middle
	"weave"	"bind"	

Other languages with regressive voicing assimilation are Hungarian and Russian.

Progressive voicing harmony is also possible, though less common than regressive voicing. One example of progressive assimilation is found in Norwegian. The (regular) past tense suffix is *-te*, and shows up as such when attached to a stem ending in a sonorant or voiceless consonant, but after a voiced obstruent, the suffix appears as *-de*.

(26)	smil-e	smil-te	"smile"
	svøm-e	svøm-te	"swim"
	hør-e	hør-te	"heard"
	lon-e	lon-te	"borrow"
	les-e	les-te	"read"
	spis-e	spis-te	"eat"
	reis-e	reis-te	"travel"
	çøp-e	çøp-te	"buy"
	tenk-e	tenk-te	"think"
	behøv-e	behøv-de	"belong"
	lev-e	lev-de	"lived"
	prøv-e	prøv-de	"try"
	bygg-e	byg-de	"build"
	hugg-e	hugg-de	"chop"
	gnag-e	gnag-de	"gnaw"
	krev-e	krev-de	"request"
	sag-e	sag-de	"saw"
	plag-e	plag-de	"afflict"
	düg-e	düg-de	"be fitting"

Another example of progressive voicing harmony is found in Evenki, where an underlyingly voiced suffix-initial consonant becomes devoiced after a voiceless obstruent: this is illustated below with the accusative case suffix /ba/.

(27)	asi:-ba	'woman'	ɲami:-ba	'female deer'
	palatka-ba	'tent'	tolgolki:l-ba	'sleds'
	ber-be	'onion'	huna:t-pa	'girl'
	det-pe	'tundra'	mit-pe	'1 pl inclusive'

Complete assimilation of a consonant to a following consonant is found in Arabic. In the data of (28) from the Syrian dialect, the consonant /l/ of the definite article assimilates completely to a following coronal consonant. Examples in (a) show non-assimilation when the following consonant is non-coronal, and those in (b) provide stems that begin with coronal consonants.

		Indefinite	*Definite*	
(28)	a.	hawa	lhawa	"air"
		ba:red	lba:red	"cold"
		ʔadham	lʔadham	"black"
		madīne	lmadīne	"city"
		ʕa:de	lʕa:de	"custom"
		ħa:ra	lħa:ra	"quarter"
		waħš	lwaħš	"beast"
		yaʔs	lyaʔs	"despair"
		kalb	lkalb	"dog"
		xadd	lxadd	"cheek"
		fayy	lfayy	"shadow"
		γada	lγada	"lunch"
	b.	sˤaff	sˤsˤaff	"row"
		ta:let	tta:let	"third"
		taxt	ttaxt	"bed"
		raʔbe	rraʔbe	"neck"
		nəde	nnəde	"dew"
		līfe	llīfe	"fiber brush"
		difa:ʕ	ddifa:ʕ	"defense"
		smīke	ssmīke	"thick"
		šo:raba	ššo:raba	"soup"
		žamīl	žžamīl	"pretty"
		zaki	zzaki	"bright"
		tˤa:leb	tˤtˤa:leb	"student"
		zˤa:bet	zˤzˤa:bet	"officer"
		dˤahu:k	dˤdˤahu:k	"jolly"

Consonants are also often susceptible to assimilation of features from a neighboring vowel, especially place features of a following vowel. One process is palatalization, found in Russian. A consonant followed by a front vowel takes on a palatal secondary articulation from the vowel, as the following data show.

(29)	vkus	"taste"	vkus^{y}-en	"tasty"
	um	"intellect"	um^{y}-en	"clever"
	golot /d/	"hunder"	golod^{y}-en	"hunger"
	stol	"table"	stol^{y}-e	"table (loc.)"
	guba	"lip"	gub^{y}-e	"lip (loc.)"
	mesto	"place"	mest^{y}-e	"place (loc.)"
	glub-ok	"deep"	glub^{y}-ina	"depth"
	ton-ok	"thin"	ton^{y}-ina	"thinness"
	vor	"thief"	vor^{y}-iska	"thief (pejorative)"
	dom	"house"	dom^{y}-iska	"house (pejorative)"
	gorot /d/	"town"	gorod^{y}-iska	"town (pejorative)"

A second kind of palatalization is found in many languages, where typically velar but in some languages also alveolar consonants become alveopalatals: to avoid confusion with the preceding type of palatalization as secondary articulation, this latter process is often referred to as **coronalization**. This process is found in Russian: it is triggered by some derivational suffixes with front vowels, but not all suffixes.[3]

(30)	druk /g/	"friend"	druž-it^{y}	"to be friends with"
	muka	"torment"	muč^{y}-it^{y}	"to torment"
	grex	"sin"	greš-it^{y}	"to sin"
	strok /g/	"strict"	strož-e	"stricter"
	dik	"wild"	dič^{y}-e	"wilder"
	sux	"dry"	suš-e	"stricter"
	krut	"steep"	kruč^{y}-e	"steeper"
	gad-ok	"foul"	gaž-e	"fouler"
	vis-ok	"tall"	viš-e	"taller"
	niz-ok	"low"	niž-e	"lower"

[3] The alveopalatal fricatives *š, ž* are not phonetically palatalizable in Russian, whereas the alveopalatal affricate is always palatalized.

Another common vowel-to-consonant effect is affrication of coronal obstruents before high vowels. An example of this is found in Japanese, where /t/ becomes [t^s] before [u] and [č] before [u].

(31)	*negative*	*provisional*	*infinitive*	*volitional*	
	mat-anai	mat-eba	mat^s-u	mač-itai	"wait"
	tat-anai	tat-eba	tat^s-u	tač-itai	"stand"
	kat-anai	kat-eba	kat^s-u	kač-itai	"win"

Outside of the domain of assimilations in place of articulation, the most common segmental interaction between consonants and vowels (or, sometimes, other sonorants) is **lenition** or **weakening**. Typical examples of lenition either involve the voicing of voiceless stops, or the voicing and spirantization of stops: the conditioning context is a preceding vowel, sometimes a preceding and following vowel. An example of the spirantization type of lenition is found in Spanish, where the voiced stops /b,d,g/ become voiced spirants [β,ð,γ] after vowels.

(32)	*N*	*with N*	*there are N's*	
	burro	kom burro	ay βurros	'donkey'
	deðo	kon deðo	ay ðeðos	'finger'
	gato	koŋ gato	ay γatos	'cat'

This can be seen as assimilation of the value [continuant] from a preceding vowel.

An example of combined voicing and spirantization is found in Tibetan, where voiceless non-coronal stops become voiced spirants between vowels.

(33)	*past affirmative*	*past negative*	*gloss*
	čaa-βəree	ma-čaa-βəree	'go'
	paa-βəree	ma-βaa-βəree	'light'
	pii-βəree	mə-βii-βəree	'renounce'
	kuu-βəree	mə-γuu-βəree	'wait'
	kə-βəree	mə-γə-βəree	'hide'
	qɔɔ-βəree	ma-ʁɔɔ-βəree	'take time out'

In some cases, the result of lenition is a glide, so in Axininca Campa, stem-initial /k,p/ become [y,w] after a vowel.

(34)				
	yaarato	"black bee"	no-yaaratoti	"my black bee"
	kanari	"wild turkey"	no-yanariti	"my wild turkey"
	kosiri	"white monkey"	no-yosiriti	"my white monkey"
	$pač^h$aka	"gourd"	no-$wač^h$akati	"my gourd"
	porita	"small hen"	no-woritati	"my small hen"

The converse process, whereby spirants, sonorants, or glides become obstruent stops after consonants, is also found in a number of languages — this process is generally referred to as **hardening**. In Kimatuumbi, sonorants become voiced stops after a nasal. The data in (35) illustrate this phenomena with the alternation in stem-initial consonant found between the singular and plural.

(35)	lu-laála	"pepper plant"	n-daála	"pepper plants"
	lu-límí	"tongue"	n-dími	"tongues"
	lu-yímá	"pole"	ñ-ǰíma	"poles"
	lu-yóká	"stomach worm"	ñ-jóka	"stomach worms"
	yúkuta	"to be full"	ñ-jukútá	"full"
	wá	"to die"	ŋ-gwaá.á	"dead"
	wíkılya	"to cover"	ŋ-gwıkílyá	"covered"
	líndıla	"to guard"	n-dındílá	"guarded"
	lyá	"to eat"	n-dyaá.á	"eaten"

Another context where hardening is common is when the consonant is geminate. One example is found in Fula, where geminate spirants become stops. In (36), plural forms have a medial geminate (this derives by an assimilation to a following *d*, so that [cabbi] derives from /caw-dī/ via the intermediate stage *cawwi*).

(36)	pl	dim sg	
	čabbi	čawel	"stick"
	lebbi	lewel	"month"
	pobbi	powel	"hyena"
	ɲɛbbɛ	ɲewel	"bean"
	leppi	lefel	"ribbon"
	koppi	kofel	"ear"
	čoppi	čofel	"chick"

Geminate hardening also occurs in Luganda. In the data of (37), the singular form of nouns in this particular class is formed by geminating the initial consonant: the underlying consonant is revealed in the plural.

(37)	*singular*	*plural*	
	ggi	ma-gi	"egg"
	ddaala	ma-daala	"ladder"
	ǰǰuba	ma-yuba	"dove"
	gg^{w}aanga	ma-waanga	"nation"
	ddaanga	ma-laanga	"lily"

In this language, only sonorants harden to stops.

(38)

singular	*plural*	
ffumu	ma-fumu	"spear"
ffuumbe	ma-fuumbe	"civet"
ssaanja	ma-saanja	"dry plaintain leaf"
zzike	ma-zike	"chimpanzee"
zziga	ma-ziga	"tear"
vviivi	ma-viivi	"knee"

2.2. Dissimilation

Less common in the languages of the world are processes of dissimilation, whereby one of two similar consonants changes to become less like the other. An example of such a process is lateral dissimilation found in Sundanese. In this language, the plural is formed by infixing *-ar-* after the initial consonant, as seen in (39a). When another *r* follows within the stem, the *r* of the infix dissimilates to *l*.

(39)

Singular	*Plural*	
kusut	k-ar-usut	"messy"
damaŋ	d-ar-amaŋ	"well"
poho	p-ar-oho	"forget"
gətol	g-ar-ətol	"diligent"
ŋoplok	ŋ-ar-oplok	"flop down"
ŋuliat	ŋ-ar-uliat	"stretch"
tuwaŋ	t-ar-uwaŋ	"eat"
manehna	m-ar-anehna	"3rd person"
masak	m-ar-asak	"cook"
ŋɨrɨt	ŋ-al-ɨrɨt	"cut"
nugar	n-al-ugar	"dig up"
combrek	c-al-ombrek	"cold"
bocor	b-al-ocor	"leaking"
bɨŋhar	b-al-ɨŋhar	"rich"
hormat	h-al-ormat	"respect"

A similar process affects the adjectival suffix -a:lis in Latin, where /l/ dissimilates to [r] if the preceding stem contains another /l/.

(40)

nava:lis	"naval"	episcopa:lis	"episcopal"
sola:ris	"solar"	milita:ris	"military"
lupana:ris	"whorish"		

Dissimilation of aspiration is attested in various languages, such as Manipuri. In (41), the first consonant of the directional suffixes *-t^hok* and *-k^hət* deaspi-

rates if preceded by another aspirate or *h* (and if the immediately preceding segment is a vowel or sonorant, the consonant becomes voiced).

(41)	pi-t^{h}ok	"give out"	pi-k^{h}ət	"give upwards"
	cət-t^{h}ok	"go out"	cət-k^{h}ət	"go upwards"
	k^{h}ik-tok	"sprinkle out"	k^{h}ik-kət	"sprinkle upwards"
	hut-tok	"bore out"	hut-kət	"bore upwards"
	k^{h}oy-dok	"trim out"	k^{h}oy-gət	"trim upwards"
	t^{h}in-dok	"pierce out"	t^{h}in-gət	"pierce upwards"

Many Bantu languages such as Kikuria have a voicing dissimilation process whereby *k* becomes *g* when the following syllable has a voiceless consonant (excluding *h*). This results in alternations in the form of the infinitive prefix which is underylyingly /oko/, as well as the 2sg object prefix /ko/ and the (diminutive) object prefix /ka/. The data in (42a) motivate the underlying prefix /oko/ and (42b) shows application of dissimilation to the prefix. (42c) shows the object prefixes /ko/ and /ka/ which also dissimilate, and (42d) shows the contrasting prefixes /go/ and /ga/ which have underlyingly voiced consonants, and do not assimilate.

(42)	a.	oko-réma	"to cultivate"	uku-ñáhaaréka	"to be hurt"
		uku-míñooŋgóra	"to crush"	uku-gííŋgírá	"to shave"
		oko-gɔ́ɔ́gá	"to slaughter"	uku-búna	"to break"
		oko-bɔ́cha	"to vomit"	oko-hóóra	"to thresh"
	b.	ogo-tááŋgá	"to begin"	ugu-túúhá	"to be blunt"
		ugu-súraaŋgá	"to sing praise"	ogo-sɛ́ɛ́nsá	"to winnow"
		ugu-kyá	"to dawn"	ogo-kɛ́ña	"to run"
	c.	ogo-kó-bárǎ	"to count you sg"		
		uku-gú-súraáŋga	"to praise you sg"		
		ogo-ká-bárǎ	"to count it"		
		oko-gá-súraáŋga	"to praise it"		
	d.	oko-gó-bárǎ	"to count it"	uku-gú-súraáŋga	"to praise it"
		oko-gá-bárǎ	"to count them"	oko-gá-súraáŋga	"to praise them"

The language Chukchi has a number of dissimilatory processes. One of these dissimilates nasality, by changing *ŋ* to *γ* before a nasal.

(43)	tara**ŋ**-ək	"build a dwelling"	nə-tara**γ**-more	"we built a dwelling"
	mətłə**ŋ**-ən	"five"	mətłə**γ**-more	"we five"
	enawrə**ŋ**-ək	"to give as a gift"	enawrə**γ**-nen	"he gave it"
	petʔi**ŋ**	"cold"	petʔi**γ**-ŋinqey	"boy with a cold"

A second dissimilation in the language changes the first in a sequence of identical fricatives to a stop.

(44)	meni**γ**	"cloth"	mane**k**-γəpə	"from cloth"
	ətłə**γ**-ən	"father"	ətłə**k**-γəyiwq-ew	"paternal marking"
	rəγrə**γ**	"wool"	rəγrə**k**-γəpə	"from wool"
	yeγte**ł**-ək	"to live"	γe-yeγte**t**-łin	"he lived"
	łəmŋəłte**ł**-ək	"tell stories"	γa-łəmŋəłte**t**-łen	"told stories"
	ŋe**w**-ʔen	"woman"	ŋa**k**-waŋe-γərγ-ən	"woman's sewing"
	iłγəte**w**-ək	"to wash"	iłγəte**k**-wʔi	"he washed"

An important feature of this rule is that only homorganic clusters dissimilate. Other combinations, such as *yγ, wł,* or *łγ* remain unchanged.

(45)	kətə**yγ**at-ək	"blow"	γa-n-pera-**w-ł**en "decorated"
	ʔiw-pipiq-ə**łγ**-ən	"wolf mouse"	

Finally, the glide *y* dissimilates to *γ* before a coronal consonant.

(46)	wʔe**y**-ək	"grass"	wʔe**γ**-ti	"grasses"
	ŋin-qe**y**	"boy"	ŋen-qa**γ**-čəŋ-ən	"big boy"
	ča**y**	"tea"	ča**γ**-nałk-ək	"to make tea"
	qe**y**-we	"correct"	qe**γ**-łənanγet	"truth"
	qeyəqe**y**	"nestling"	qa**γ**-yaʔyaq	"young seagull"

Dissimilation between vowels is also found in languages. One case comes from Woleiaian, where the low back vowel /a/ becomes [e] before the low back vowels /a/ and /ɔ/. This process affects the causative prefix /ga/, seen below.

(47)	ga-repa	"approach it"	ga-beši	"heat it"
	ga-**s**iwe	"make it stand"	ga-sere	"make it hit"
	ge-bbaro	"bend it"	ge-mak**i**	"give birth to him"
	ge-mɔwe	"erase it"	ge-tɔtɔwe	"support it"
	ge-was**i**r	"hurt it"	ge-tɔla	"make it bloom"

In Wintu, the vowels /e, o/ become [i,u] before /a/ by a similar kind of dissimilation.

(48)	/lel-a/	→	lila	"to transform"
	/lel-u/	→	lelu	"transform!"
	/lel-it/	→	lelit	"transformed"
	/dek-a/	→	dika	"to climb"

/dek/	→	dek	"climb!"
/dek-na:/	→	dekna:	"to step"
/doy-a:/	→	duya:	"to give"
/doy-u/	→	doyu	"give!"
/doy-i/	→	doyi	"gift"
/kor-a/	→	kura	"to lay out a net"
/kor-o/	→	koro	"net"

Examples of low vowel dissimilating to non-low vowels before low vowels are also found in Kera and Southern Russian. Interestingly, most examples of dissimilation between vowels are precisely of this nature: we do not seem to find cases of high vowels dissimilating to non-high near other high vowels.

2.3. Other Segmental Processes

There are other segmental processes which do not neatly fit into the category of assimilation or dissimilation. One such example is neutralization, whereby a phonetic contrast is deleted in some context, which consonants are particularly susceptible to. One case is the neutralization of laryngeal contrasts in consonants at the end of the syllable, as exemplified by Korean.

(49)

Infinitive	*Conjunctive*	
ip-ə	ip-k'o	"wear"
kup-ə	kup-k'o	"bend"
kap^{h}-a	kap-k'o	"pay back"
čip^{h}-ə	čip-k'o	"feel the pulse"
tat-ə	tat-k'o	"close"
put^{h}-ə	put-k'o	"adhere"
čoč^{h}-a	čot-k'o	"follow"
mək-ə	mək-k'o	"eat"
čuk-ə	čuk-k'o	"die"
ik-ə	ik-k'o	"ripen"
tak'-a	tak-k'o	"polish"
k'ak'-a	k'ak-k'o	"reduce expenses"
sək'-ə	sək-k'o	"mix"

Another kind of neutralization is place neutralization, which can be exemplified by Saami. Saami restricts word-final consonants to the set *t, n, r, l, s, š*, i.e. the voiceless coronal non-affricates. The data in (50) show that noun stems can end in an array of consonants, as revealed by the essive form of the noun which takes the suffix -(*i*)*n*, but in the nominative, which has no suffix, all places of articulation are neutralized to coronal.

(50)	*nominative sg.*	*essive*	
	oahpis	oahpis-in	"acquaintance"
	čoarvuš	čoarvuš-in	"antlers & skullcap"
	gahpir	gahpir-in	"cap"
	heevemeahhtun	heevemeahhtun-in	"inappropriate"
	varit	varih-in	"2 year old reindeer buck"
	čuoivvat	čuoivvag-in	"yellow-brown reindeer"
	ahhkut	ahhkub-in	"grandchild of woman"
	lottaaš	lottaaǰ-in	"small bird"
	suohkat	suohkað-in	"thick"
	jaaʔmin	jaaʔmim-in	"death"

It is interesting that Saami also neutralizes laryngeal contrasts in this position, so that voiced stops also become voiceless: it is unknown whether a language may exhibit neutralization of place contrasts without also having neutralization of laryngeal contrasts.

3. Prosodically Based Processes

A second major class of phonological processes can be termed 'prosodically motivated processes'. Such processes have an effect on the structure of the syllable (or higher prosodic units such as the 'foot'[4]), usually by inserting or deleting a consonant, or changing the status of a segment from vowel to consonant or vice versa. A very common set of prosodic processes is the class of processes which eliminate V+V sequences. Many languages disallow sequences of vowels, and when such sequences would arise by the combination of morphemes, one of the vowels is often changed. One of the most common such changes is Glide Formation, whereby a high vowel becomes a glide before another vowel. Quite often, this process is accompanied with a lengthening of the surviving vowel, a phenomenon known as compensatory lengthening. For example, in Kimatuumbi, high vowels become glides before other vowels, as shown by the data in (51). The examples on the left show that the noun prefixes have underlying vowels, and those on the right illustrate application of glide formation.

(51)	mi-kaáte	"loaves"	my-oótó	"fires"
	li-kuŋuúnda	"filtered beer"	ly-oowá	"beehive"
	ki-kálaaŋgo	"frying pan"	ky-uúlá	"frog"
	i-kálaaŋgo	"frying pans"	y-uúlá	"frogs"
	lu-toóndwa	"star"	lw-aaté	"banana hand"
	tu-tóopé	"little handles"	tw-iípʊkú	"little rats"

[4] The foot is, roughly, a grouping of two syllables into a rhythmic unit, which is primarily relevant in phonology for the description of stress assignment.

ku-suúle	"to school"	kw-iisíwá	"to the islands"
mu-kikálaaŋgo	"in the frying pan"	mw-iikálaaŋgo	"in the frying pans"

Although the stem-initial vowel is long on the surface in these examples, underlyingly the vowel is short, as shown when the stem has no prefix or when the prefix vowel is *a*. Thus, compare *ka-ótó* "little fire", *ma-owá* "beehives", *ka-úlá* "little frog", *até* "banana hands", *ipʊkó* "rats".

Vowel sequences can also be eliminated by coalescing the two vowels into a single vowel, often one which preserves characteristics of the individual vowel. This happens in Kimatuumbi as well, where the combinations /au/ and /ai/ become [oo] and [ee].[5] This rule is optional in Kimatuumbi, so the uncoalesced vowel sequence can also be pronounced (thus motivating the underlying representation).

(52)	a-i-téliike	ee-téliike	"he cooked them"
	pa-ú-kaátité	poó-kaátité	"when you cut"
	pa-bá-i-káatité	pa-bée-káatité	"when they cut them"
	a-u-káatite	oo-káatite	"he cut it"
	ka-u-tʊʊmbúka	koo-tʊʊmbúka	"when it was falling"
	pa-i-taábu	pee-taábu	"where the books are"
	pa-u-títili	poo-títili	"where the chicken louse is"
	ka-u-méyá	kooméyá	"little white ant"
	na-u-čaápu	noo-čaápu	"with dirt"

The change of /au/ and /ai/ to [oo] and [ee] can be seen as creating a compromise vowel, one which preserves the height of the initial vowel /a/, and the backness and roundness of the second vowel.

Sometimes, vowel sequences are avoided simply by deleting one of the vowels, with no compensatory lengthening. Thus at the phrasal level in Shimakonde, word-final /a/ deletes before an initial vowel, cf. *lipeeta engaanga* → *lipeet engaanga* 'the knapsack, cut it!', *likuka engaanga* → *likuk engaanga* 'the trunk, cut it!', *nneemba idanaao* → *nneemb idanaao* 'the boy, bring him!'.

The converse process of vowel epenthesis is also quite common. One context that often results in epenthesis is when an underlying form has too many consonants in a row, given the syllable structure of the language. Insertion of a vowel then reduces the size of the consonant cluster. An example of such epenthesis is found in Fula. In this language, no more than two consonants are allowed in a row. As the data of (53) show, when the causative suffix /-na/ is added to a stem ending in two consonants, the vowel *i* is inserted, thus avoiding three consecutive consonants.

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[5] In this language, coalescence only applies in a specific grammatical domain, between vowels of prefixes, and thus one does not find this same process affecting the prefix-plus-stem combination found in *ka-úlá* "little frog".

(53)	*continuous*	*causative*	
	hula	hulna	"laugh"
	yara	yarna	"drink"
	woya	woyna	"cry"
	ǰu:la	ǰu:lna	"be Muslim"
	wurto	wurtina	"come out"
	wuǰǰa	wuǰǰina	"steal"
	yotto	yottina	"arrive"

A related result of vowel epenthesis is that it to eliminates certain kinds of consonants in a particular position. The only consonants at the end of the word in Kotoko are sonorants, so while the past tense of the verbs in (54a) is formed with just the stem, the verbs in (54b) require final epenthetic schwa.

(54)		*Infinitive*	*Past*	
	a.	hàm-à	hám	"yawn"
		ɗàn-à	ɗàn	"tie"
		skwàl-à	skwál	"want"
		vèr-à	vèr	"fly"
		ləhày-à	ləhày	"fear"
		làw-à	làw	"fight"
	b.	gəɓ-à	gəɓə̀	"answer"
		kàɗ-à	káɗə́	"cross"
		làb-à	làbə̀	"tell"
		ǰàg-à	ǰàgə̀	"cook"
		gìč-à	gìčə́	"sweep"
		ʔək-à	ʔəkə́	"take by force"
		sàp-à	sapə́	"chase"
		vìt-à	vìtə́	"blow on a fire"
		vənàh-à	vənàhə̀	"vomit"
		həs-à	həsə́	"spill"
		ɗəv-à	ɗəvə̀	"put"
		bàγ-à	bàγə̀	"split wood"

Another factor motivating epenthesis is a word-size, viz. the need to avoid monosyllabic words. One example is seen in the following data from Mohawk, where the 1 sg. prefix is preceded by the vowel *i* just in case is it attached to a monosyllabic stem.

(55)	k-atirút-haʔ	"I pull it"
	k-ataʔkeráhkwaʔ	"I float"
	k-kétskw-as	"I raise it"
	k-hní:nus	"I buy"
	k-tat-s → íktats	"I offer it"
	k-yʌ-s → íkyʌs	"I put it"
	k-ket-s → íkkets	"I scrape it"

The adaptation of loanwords into Saami from Scandinavian languages (Norwegian or Swedish) illustrates a variant on the Mohawk-type minimal-word motivation for epenthesis. In this case, a vowel is inserted to prevent a monosyllabic stress foot — though interestingly this requirement is determined on the basis of the Norwegian source, whereas in the Saami word stress is (predictably) on the first syllable. Except for a small set of "special" words (pronouns, grammatical words), words in Saami must be at least two syllables long. Thus the appearance of a final epenthetic vowel in the following loanwords is not surprising.

(56)	*Saami*	*Norwegian*	
	daaigi	deig	'dough'
	niibi	kniv	'knife'
	vouʔna	vogn	'wagon'
	muura	mur	'wall'

In contrast, in the following loanwords there is no epenthetic vowel. The location of stress, which is the key to understanding this problem, is marked on the Norwegian source though stres is not marked in the orthography.

(57)	*Saami*	*Norwegian*	
	diisdat	tírsdag	'Tuesday'
	kaavrret	kávring	'rusk'
	akaðemihkar	akadémiker	'academic'
	miniistar	minister	'minister'
	teahter	teáter	'theater'
	tempel	témpel	'temple'
	orgel	órgel	'organ'
	profes'sor	professor	'professor'
	plasttar	pláster	'plaster'
	kaahkal	kákkel	'glazed tile'

The above examples are ambiguous in analysis, since the source word is both polysyllabic, and has a non-final stress. The examples in (58), on the other hand, show epenthesis when the stress-foot in the source word is monosyllabic, even though the overall word is polysyllabic.

(58)	hoteella	hotéll	'hotel'
	maratona	maratón	'marathon'
	universiteehta	universitét	'university'
	tabeal'la	tabéll	'(time-)table'
	privaahta	privát	'private'
	kameela	kamél	'camel'
	polaara	polár	'polar'

Consonants can also be inserted. The most common cause of consonant insertion is the avoidance of initial vowels or vowel sequences. In Arabic all syllables begin with a consonant, and and if a word has no underlying initial consonant a glottal stop is inserted, thus /al-walad/ → [ʔalwalad] "the boy". In the Hare & Bearlake dialects of Slave, words cannot begin with a vowel, so when a vowel-initial root stands at the beginning of a word (including in a compound), the consonant *h* is inserted.

(59)	s-õdee	"my older brother"
	dene-[h]õdee	"Brother (in church)"
	n-anay	"your sg. sister-in-law (man speaking)"
	[h]anay	"sister-in-law"
	b-ek'éhdí	"I take care of him/her"
	bebí [h]ek'éhdí	"I take care of the baby"
	ku-edehfe → kúdehfe	"I chased them"
	sah [h]edéhfe	"s/he chased the bear"

In Axininca Campa *t* is inserted between vowels — this language does not have a glottal stop phoneme. Thus, /i-N-koma-i/ → [inkomati] "he will paddle".

Deletion of consonants can be found in languages. The most common factor motivating consonant deletion is the avoidance of certain kinds of consonant clusters — a factor which also can motivate vowel epenthesis. Consonant cluster simplifiation is found in Korean.

(60)	infinitive	conjunctive	indicative	gloss
	palp-a	pal-k'o	pal-t'a	tread on
	ulph-ə	ul-k'o	ul-t'a	chant
	ilk-ə	il-k'o	il-t'a	read
	halth-a	hal-k'o	hal-t'a	taste
	talm-a	tam-k'o	tam-t'a	resemble
	anc-a	an-k'o	an-t'a	sit down

Another cause of cluster simplification is the avoidance of certain specific types of consonant clusters. Shona avoids clusters of the form Cy although Cw is

perfectly acceptible. The deletion of *y* after a consonant affects the form of possessive pronouns in various noun classes. Demonstratives and possessive pronouns are formed with an agreement prefix reflecting the class of the noun, plus a stem, -*no* for "this" and -*angu* for "my". Before the stem -*angu*, a high vowel becomes a glide. Just in case this would result in a Cy sequence, the glide is deleted.

(61)	'this'	'my'	class
	u-no	w-angu	3
	mu-no	mw-angu	18
	ku-no	kw-angu	17
	ru-no	rw-angu	11
	i-no	y-angu	9
	ri-no	r-angu	6
	či-no	č-angu	7
	ẓ^{w}i-no	ẓ^{w}-angu	8
	d^{z}i-no	d^{z}-angu	10

Since /i-angu/ becomes *yangu*, it is evident that the vowel *i* does become a glide before a vowel.

Processes lengthening stressed vowels are also rather common. An example of stress-induced vowel lengthening is found in Makonde, where the penultimate syllable is stressed, and the stressed vowel is always lengthened.[6]

(62)		
	kú-ˈlíím-a	"to cultivate"
	kú-líˈm-ííl-a	"to cultivate for"
	kú-líˈm-áán-a	"to cultivate each other"
	kú-lím-áˈn-ííl-a	"to cultivate for each other"
	kú-lím-án-íl-á-lím-áˈn-ííl-a	"to cultivate for each other continuously"

A related process is the reduction of unstressed vowels, as found in English. From alternations like *bərɔ́mətr̩ ~ bɛ̀rəmɛ́trɪk*, *mɔ́nəpɔ̀wl ~ mənɔ́pəliy*, we know that unstressed vowels in English are reduced to schwa. Russian also reduces unstressed nonhigh vowels so that /a,o/ become [ə], or [a] in the syllable immediately before the stress.

(63)		
	/gorod-ók/ → [gəradók]	"cities"
	/górod/ → [górəd]	"city"
	/pó-da-l/ → [pódəl]	"he gave"
	/po-dá-t^{y}/ → [padát^{y}]	"to give"

[6] Since Makonde is also a tone language and the accute accent is used to mark H tone, not stress, stress will be indicated with the mark 'ˈ' before the stressed syllable.

Reduction of unstressed vowels can go all the way to deletion, so in Palestinian Arabic, unstressed high vowels in an open sylable are deleted.

(64) *Palestinian Arabic*

3sg masc	3sg fem	1s	
ḥámal	ḥámalat	ḥamált	"carry"
kátab	kátabat	katábt	"write"
dáras	dárasat	darást	"study"
šírib	šírbat	šríbt	"drink"
nízil	nízlat	nzílt	"descend"
fíhim	fíhmat	fhímt	"understand"

Many languages disallow long vowels in syllables closed by consonants, and the following examples from Yawelmani show that this language enforces such a prohibition against VVC syllables by shortening the underlying long vowel.

(65)

	nonfuture	*imperative*	*dubitative*	*passive aorist*	
/CVC/	xathin	xatk'a	xatal	xatit	'eat'
	doshin	dosk'o	do:sol	do:sit	'report'
/CVVC/	ṣaphin	ṣapk'a	ṣa:pal	ṣa:pit	'burn'
	wonhin	wonk'o	wo:nol	wo:nit	'hide'

Stress assignment has been the subject of intensive typological study, and has proven to be a fruitful area for decomposing phonological parameters. See Hayes 1995 for a survey of different stress systems. One very common stress assignment pattern is the alternating pattern, where every other syllable is assigned a stress. Maranungku exemplifies this pattern, where the main stress is on the first syllable and secondary stresses are on all subsequent odd-numbered syllables.

(66)

tíralk	'saliva'
mérepèt	'beard'
yángarmàta	'the Pleaiades'
lángkaràtetì	'prawn'
wélepènemànta	'duck (sp.)'

A variant of this pattern occurs in Araucanian, where the main stress appears on the second syllable, and secondary stresses appear on every even numbered syllable following.

(67)	wulé	'tomorrow'
	ṭipánto	'year'
	elúmuyù	'give us'
	elúaènew	'he will give me'
	kimúbalùwulày	'he pretended not to know'

The mirror image of the Maranugku pattern is found in Weri, where the last syllable has the main stress and every other syllable preceding has secondary stress.

(68)	ŋintíp	'bee'
	kùlipú	'hair of arm'
	ulùamít	'mist'
	àkunètepál	'times'

Finally, Warao places the main stress on the penultimate syllable and has secondary stresses on alternating syllables before.

(69)	yiwàranáe	'he finished it'
	yàpurùkitàneháse	'verily to climb'
	enàhoròahàkutái	'the one who caused him to eat'

Another property exhibited by many stress systems is quantity-sensitivity, where stress is assigned based on the weight of a syllable. Palestinian Arabic has such a stress system, where stress is assigned to the final syllable if that syllable is heavy, to the penult is the penult is heavy and the final syllable us light, and to the antepenult otherwise. The typical definition of a heavy syllable is one with either a long vowel ofr a final consonant; however, it should be noted that in Arabic, final syllables have a special definition for 'heavy', which is that a single consonant does not make the syllable heavy, but two consonants do.

(70)	radyóo	"radio"	qaréet	"I read"
	katábt	"I wrote"	qára	"he read"
	qárat	"she read"	katábna	"we wrote"
	qaréethum	"I read them"	kátabu	"they wrote"
	kátabat	"she wrote"	ma katabátš	"she didn't write"

4. Why do things happen?

Two of the central questions which phonological theory has sought answers to are "why does rule X exist?" and "can rule Y exist?". Very many languages have a process changing velars into alveopalatals (k → č) before front vowels, and a rule voicing voiceless stops after nasals (mp → mb) is also quite common. It is natural to wonder why such rules would occur in many languages,

and a number of theoretical explanations have been offered to explain this. It is also important to also ask about imaginable rules: we want to know, for example, if any language has a rule turning a labial into an alveopalatal before a front vowel, one devoicing a voiced stop after a nasal, or one turning {s,m} into {l,k} before {w,š}. Only by contrasting phenomena found in the universe with imagineable but unattested phenomena do theories become of scientific interest.

There is a clear and justified intuition among phonologists that the rule {s,m} → {l,k}/ __{w,š} is "unnatural", and any theory which allowed such a rule to be formulated would not be a useful theory. We have seen in Chapter 6 that it is impossible to formulate such a process given the theory of distinctive features, since the classes of segments that define target and trigger, and the nature of the structural change, cannot be expressed in the theory. The fact that neither this rule nor any of the trillions of other logically conceivable analogous random pairings of segments into rules has ever been attested in any language gives us a basis for believing that phonological rules should at least be "possible", in the very simple sense technical expressed by feature theory.

Another pair of rules which we might wonder about are those in (71).

(71)	a.	mč → ñč	ŋč → ñč
		ñp → mp	np → mp
		ñk → ŋk	nk → ŋk
		ñt → nt	nč → ñč
	b.	mč → nč (not ñč)	ŋč → ñč
		ñp → ŋp	np → mp
		ñk → ŋk	nk → mk
		ñt → ñt	nč → nč

The pattern of alternation in (a) is quite common, and was exemplified earlier in this chapter as nasal place assimilation. The second pattern of alternation in (b), on the other hand, is not attested in any language. Given the nonexistence of the pattern (b), we may ask "why is this pattern not attested".

The easy answer to this question is that pattern (b) is not phonetically natural. This begs the question of how we know what is a phonetically natural versus an unnatural pattern, and unfortunately the connection between "actually attested phonological rule" and "phonetically natural" are so closely intertwined that people assume that commonly occurring rules are by definition phonetically natural, and unattested rules are phonetically unnatural. This is circular: if we are to preclude a pattern such as (b) as phonetically unnatural, there must be an independent metric of phonetic naturalness. Otherwise, we would simply be saying "such-and-such rule is unattested because it is unattested", which is a pointless tautology.

Another answer to the question of why pattern (b) is not attested, but pattern (a) is, would appeal to a formal property of phonological theory. We will tem-

porarily forgo a detailed analysis of how these processes can be formulated — this is taken up in Chapter 11 — but in one theory, the so-called linear theory practiced in the 60's and 70's, there was also no formal explanation for this difference, whereas in the nonlinear theory introduced in the late '70's, there is a very clear explanation. The earlier linear theory of rules made it quite easy to describe the pattern in (b), using the so-called feature variable notation. The rule which would be necessary to describe pattern (b) is not a formally possible rule in the nonlinear theory. The mechanism used in the nonlinear theory to describe processes where the output has a variable value (i.e. the result can be either [+anterior] or [-anterior], [+coronal] or [-coronal]) requires the target segment to take the *same* values for the features, and also requires the target to take on *all* values of certain feature sets. The alternation in (b) does not have this property (for example the change of /ñp/ to [ŋp] does not include copying the value of the feature [labial]), and therefore according to the nonlinear theory this is an unformalizable rule. This process is predicted to be unattested in human language. So in some cases, the answer to the question "is X a possible rule" depends on the theory assumed.

Now consider the possibility of a rule p → č / __{i,e}, which seems hardly different from the rule k → č / __{i,e}, except that the latter rule is very common, and the former rule is apparently not found in any language. Since we don't know of examples, we must wonder why there is such a gap in what is attested. Perhaps if we had the "right theory", every rule that is possible under a theory would actually be attested in some language. In both the linear and non-linear theories, these are both technically possible rules.

One legitimate strategy is to assume that this is an accidental gap, so we presume that further research will eventually turn up such a rule. Given that only a tiny fraction of the world's languages have been suveyed, this is reasonable. There is a bit of danger in assuming that the apparent nonexistence of labial coronalization is an accidental gap, because we don't want to also ignore the nonexistence of the conceivable rule /s,m/→[l,k]/__[w,š] as another accidental gap.

The difference between these two kinds of rules lies in an implicit estimation of how big the gap is between prediction and observation. A number of rules would fall under the rubric 'labial coronalization', which would be formalizable under standard feature theories:

(72) p → č / __ i p,b → č,ǰ / __i
p → č / __i,e p,f,b → č,š,ǰ /__i,e
etc.

If it turns out that the rules /p/ → [č] / __ [i], /p/ → [č] / __[i,e] and /p,f,b/ → [č,š,ǰ] /__[i,e] were all attested and only the rule /p,b/ → [č,ǰ] / __[i] is missing, there would be no question that this is an accidental gap. The number of rules

which theoretically can be formulated in standard theories is quite large,[7] running in the thousands or millions, so if we can't find some one, or some dozen particular rules, in the hundred or so languages that we have looked at, this shouldn't cause serious concern because the chances of finding *any* one rule at random, out of the set of theoretically possible rules, is fairly low and is of no more significance that a failure to toss a million-sided coin a few hundred times and not have the coin land with side number 957,219 land on top.

We should be a bit more concerned when we identify a somewhat large class — hundreds or perhaps even a thousand — of possible rules which are all unattested and which seem follow a discernable pattern (i.e. "alveopalatalization of labials"). Remember though that we are dealing with a million-sided coin and only a few hundred tosses of the coin. The unattested set of rules represents perhaps a tenth of a percent of the logically possible set, and given the small size of the sample of phonological rules actually available to us, the chances of actually finding such a rule is still not very high.

The situation with the rule /s,m/ → [l,k] / __[w,š] is quite different. This rule is a representative of an astronomically large class of imaginable rules, formed by combining any set of phonemes in the input, any set of phonemes in the context, and any set of replacements. To put in perspective the predictions of a theory where rules are unstructured collections of segments changing randomly in arbitrary contexts, consider the fact that if we start with just 8,192 segments ($=2^{13}$), there are over 187 trillion ways to construct sets of 4 segments, over $10^{2,466}$ possible sets of segments (in comparison, the theory of distinctive features allows construction of around 10^6 classes), and about $10^{7,400}$ possible rules, in comparison to perhaps a billion rules with standard rule theory. Almost every rule which is theoretically predicted under the "random segment" theory falls into the class of rules of the type /s,m/ → [l,k] / __[w,š], and yet not a single one of these rules has been attested: probability theory, on the other hand, says that virtually every attested rule should be of this type, given how many imagineable, phonetically arbitrary changes there are. This is why the lack of rules of the type /s,m/ → [l,k] / __[w,š] is theoretically significant — it represents the tip of a mammoth iceberg of failed predictions of the "random phoneme" theory of rules.

Since the computational theory provides no basis for thinking that labial coronalization is impossible, we can just assume that the gap results from a too-small sample. On the other hand, it is also possible that our theory is wrong, and that some other theory, one yet to be articulated, may provide a principled explanation for the lack of such a rule. This has happened before in the history of linguistics (and all science), and it will happen again. A theory predicts the existence of a particular class of phenomenon; people will note that a particular exemplar

[7] This number has never been calculated, partly because the nature of the theory (hence the characterization "theoretically possible rule") changes rather rapidly, and partly because phonologists aren't usually concerned with combinatorics.

does not seem to be attested; it will be assumed that an example will eventually show up; concerted efforts to find examples fail, and more and more examples of the gap between theory and data accumulate. At some point, a new theory is proposed, and suddenly it is realised that there is no mystery why such examples are missing — the new theory predicts that they should not exist. In the case of the two sets of nasal changes in (71), prior to the advent of the nonlinear theory, the nonexistence of processes like (71b) was assumed to be an accidental gap. No such examples ever materialised, and with clear hindsight, we realise that this is because the earlier theory simply made a bad prediction.

Another way to cope with this gap is to seek an explanation from outside the domain of phonological theory itself. An analog would be the explanation for why arctic mammals have small furry ears and desert mammals have larger naked ears, proportionate to the size of the animal. There is no independent "law of biology" that states that ear size should be directly correlated with temperature, but this observation makes sense given a little knowledge of the physics of heat radiation and the basic structure of ears. In a nutshell, you lose a lot of body heat from big ears, which is a good thing in the desert and a bad thing in the arctic. Perhaps there is an explanation outside of the domain of phonological theory itself for the lack of labial coronalization in the set of rules attested rules.

What then might be the functional explanation for the lack of such a process? We first need to understand what might be a theory-external, functional explanation for the existence of the common change k → č/ __ {i,e}. In a vast number of languages, there is some degree of fronting of velar consonants to [k^y] before front vowels. The reason for this is not hard to see: canonical velars have a further back tongue position, and front vowels have a further front tongue position. To produce [ki], with a truly back [k] and a truly front [i], the tongue body would have to move forward a considerable distance, essentially instantaneously. This is impossible, and some compromise is required. The compromise reached in the vast majority of languages is that the tongue advances in anticipation of the vowel [i] during production of [k], resulting in a palatalized velar, i.e. the output [k^yi], which is virtually the same as [ci], with a "true palatal" stop. The actual amount of consonantal fronting before front vowels that is found in a language may vary from the barely perceivable to the reasonably evident (as in English) to the blatantly obvious (as in Russian). This relatively small physiological change of tongue-fronting has a disproportionately more profound effect on the actual acoustic output. Essentially, a plain [k] sounds more like a [p] that it sounds like [c] ([k] has a lower formant frequency for the consonant release burst), and [c] sounds more like [t] or [č] (in having a higher burst frequency) than it sounds like [k], which it is physiologically more similar to. The acoustic similarity of alveopalatals like [č] and palatals like [c] is great enough that it is easy to confuse one for the other. Thus a child learning a language might (mis)interpret a phonetic alternation [k] ~ [c] as the alternation [k] ~ [č].

Explaining why k → č / __{i,e} *does* exist is a first step in understanding the lack of labial coronalization before front vowels. The next question is whether there are analogous circumstances under which our unattested rule might also come into existence. Since the production of [p] and the production of [i] involve totally different articulators, a bit of tongue advancement for the production of [i] will have a relatively negligible effect on the acoustics of the release burst for the labial, and especially will not produce a sound that is likely to be confused with [č]. The constriction in the palatal region will be more open for /i/ after the release of /p/, because the tongue does not already produce a complete obstruction in that region (a maximally small constriction) as it does with /k/. It is possible to radically advance the tongue towards the [i]-position and make enough of a palatal constriction during the production of a [p] so that a more [č]-like release will result, but this will not happen simply as a response to a small physically motivated change, as it does with /k/. Thus the probability of such a change — p → č — coming about by phonetic mechanisms is very small, and to the extent that phonological rules get their initial impetus from the grammaticalization of phonetic variants, the chances of ever encountering labial coronalization are slim.

Another approach which might be explored focuses on articulatory consequences of velar coronalization versus labial coronalization. Velar and alveolars involve the tongue as their major articulator, as does [č], whereas labials do not involve the tongue at all. We might then conjecture that there is some physiological constraint that prevents switching major articulators, even in phonological rules. But we *can't* just say that labial never become linguals: they typically do in nasal assimilation. In fact, there is a phonological process in the Nguni subgroup of Bantu languages (Zulu, Xhosa, Swati, Ndebele), where at least historically labials become alveopalatals before *w*, which is very close to the unattested process which we have been looking for. By this process, a labial consonant becomes a palatal before the passive suffix -*w*-, as in the following data from SiSwati.

(73)	*active*	*passive*	*gloss*
	kú-k^{h}ándíŋ-a	kú-k^{h}ándíŋ-w-a	dry roast
	kú-káp^{h}-a	kú-káš-w-a	chop
	kú-k^{x}éb^{h}-a	kú-k^{x}éj-w-a	scrape
	kú-lúm-a	kú-lúñ-w-a	bite
	kú-n|wáb-a	kú-n|wác-w-a	bury

This is a clear counterexample to any claim that labials cannot switch major articulator, and is a rather odd rule from a phonetic perspective (as pointed out by Ohala 1978). Rather than just leave it at that, we should ask how such an odd rule could have come into existence. In a number of Bantu languages, especially those spoken in southern Africa, there is a low-level phonetic process of velarization and unrounding where sequences of labial consonant plus [w] are pronounced with decreased lip rounding and increased velar constriction, so that underlying

/pw/ is pronounced as [p^{ɯ}], with [^{ɯ}] notating a semi-rounded partial velar constriction. The degree of velar constriction varies from dialect to dialect and language to language, and the degree of phonetic constriction increases as one progresses further south among the Bantu languages of the area, so in Karanga Shona, /pw/ is pronounced with a noticeable obstruent-like velar fricative release and no rounding, as [p^{x}]. The place of articulation of the velar release shifts further forward depending on the language and dialect, being realised as [p^{ç}] in Pedi, or as [p^{š}] in Sotho, and finally as [č] in Nguni. So what seems like a quite radical change, given just the underlying-to-surface relation /p/ → [č] in Nguni, is actually just the accumulated result of a number of fortuitously combined, less radical steps.

One of the current debates in phonology — a long-standing debate given new vitality by the increased interest in phonetics[8] — is the question of the extent to which phonological theory should explicitly include reference to concepts rooted in phonetics, such as ease of articulation, perceptability and confusability, and issues pertaining to communicative function. Virtually every imaginable position on this question has been espoused, and it is certain that the formalist/functionalist debate will persist unresolved for decades.

[8] The increased interest in phonetics is essentially driven by the ready accessibility of very powerful computer and relatively cheap signal processing programs especially since the mid '90's. Traditionally, instrumental phonetic research required very expensive and often cantankerous equiptment with quite limited analytic capabilities, but now with the average computer, literally anyone anywhere can undertake highly sophisticated analysis of acoustic data.

9

Analytic Sketches

This chapter presents a sketch of aspects of the phonology of Kimatuumbi and Syrian Arabic. The purpose of the chapter is to give you experience with an extended analysis of a large corpus of data from a language, reinforcing the idea that the phonology of a language is built on recurring, interacting principles.

1. Kimatuumbi Prosodic Phonology

There are three closely related areas of the phonology of Kimatuumbi that relate to suprasegmental properties, namely Glide Formation which turns the high vowels *i* and *u* into the glides *y* and *w*, processes of tone assignment and tone retraction, and Phrasal Shortening which shortens long vowels in a word which is followed by another word in the phrase.

1.1. Vowel Sequences

One of the most pervasive phonological phenomena in Kimatuumbi is Glide Formation, which changes the high vowels *u* and *i* into the glides *w* and *y* before a vowel. Within a word, *u* and *i* can never stand before another vowel. One context illustrating Glide Formation arises when a noun class prefix is placed before a vowel initial stem. Nouns in Kimatuumbi are lexically or grammatically assigned to different morphological classes, which are marked by the presence of a prefix such as *mi-, li-* or *lu-*. The data in (1) provide examples of these prefixes: the example on the left demonstrates the form of the prefix before a consonant, and the corresponding example on the right demonstrates the prefix before a vowel.

(1)	mi-kaáte	'loaves'	my-oótó	'fires'
	li-kuŋuúnda	'filtered beer'	ly-oowá	'beehive'
	ki-kálaaŋgo	'frying pan'	ky-uúlá	'frog'
	i-kálaaŋgo	'frying pans'	y-uúlá	'frogs'
	lu-toóndwa	'star'	lw-aaté	'banana hand'
	tu-tóopé	'little handles'	tw-iípʊkʊ́	'little rats'
	ku-suúle	'to school'	kw-iisíwá	'to the islands'
	mu-kikálaaŋgo	'in a frying pan'	mw-iikálaaŋgo	'in frying pans'

This phonological process of Glide Formation can be formalized as follows.

(2) *Glide Formation*

$$\overset{\text{V}}{[+\text{hi}]} \rightarrow [-\text{syl}] \ / \ \_\_ \ \text{V}$$

Not only is the high vowel of the prefix replaced by an appropriate glide, but also the following vowel is long. One of the side-effects of Glide Formation is that the vowel on the right, the one which triggers the rule, becomes long by what is known as compensatory lengthening. Additional evidence can be mustered to motivate the claim that Glide Formation lengthens the following vowel. In (3) we can see pairs of words with the same stem. The examples on the left show that the stem has an underlying short vowel, which surfaces as short either when there is no prefix or when the prefix vowel is *a*. The example on the right shows the same stem after a prefix which has an underlying high vowel that undergoes Glide Formation.

(3)	ma-ótó	'large fires'	my-oótó	'fires'
	ma-owá	'beehives'	ly-oowá	'beehive'
	até	'banana hands'	lw-aaté	'banana hand'
	ka-úlá	'small frog'	ky-uúlá	'frog'
	i-pʊkʊ́	'rats'		
	pa-i-pʊkʊ́	'where the rats are'	tw-ií-pʊkʊ́	'little rats'
	i-kálaaŋgo	'frying pans'		
	pa-i-kálaaŋgo	'where frying pans are'	mw-ii-kálaaŋgo	'in frying pans'

A conceivable approach to these vowel length alternations would be to assume that the stem vowel is underlyingly long, and undergoes shortening when the vowel is word initial or preceded by another vowel. This alternative can be ruled out, since there is a lexical contrast between long and short vowels in this position. The nouns in (4) have underlying initial long vowels, and they retain that long vowel both when preceded by a prefix with a high vowel (where Glide Formation applies), when preceded by a prefix ending with *a*, and when there is no prefix.

(4)	mw-eémbe	'mango tree'	eémbe	'mango fruit'
	my-eémbe	'mango trees'	ka-eémbe	'small mango'
	ly-éeke	'storage shack'	ma-éeke	'storage shacks'
	lw-áanjú	'firewood piece'	aanjú	'firewood'
	ky-ɪímbe	'knife'	ka-ɪímbe	'small knife'
	ky-úundó	'knot'	ma-úundó	'large knots'
	mw-eéla	'in money'	eéla	'money'

Thus the supposed rule shortening word-initial and postvocalic long vowels is simply incorrect. The examples in (4) undergo Glide Formation, with no compensatory lengthening effect, since the triggering vowel is already long.

Additional motivation for Glide Formation comes from the verbal paradigm. In (5) we see examples of subject prefixes followed by the verb stem: those on the left illustrate the underlying prefix, and those on the right, before a vowel-initial stem, illustrate Glide Formation.

(5)	ni-téliike	'I cooked'	ny-ʊʊ́bɩliile	'I expected'
	tu-téliike	'we cooked'	tw-eékite	'we laughed'
	ki-tʊʊ́mbwiike	'it (7) fell'	ky-oóbite	'it (7) is lost'
	u-téliike	'you(sg.) cooked'	w-aákite	'you(sg.) hunted'

The infinitive form of the verb is given in (6), where it can be seen that underlyingly these stems begin with a short vowel, and application of Glide Formation causes the following vowel to lengthen.

(6)	ʊ́bɩlya	'to expect'	éka	'to laugh'
	óba	'to be lost'	áka	'to hunt'

Furthermore, when these stems are preceded by the vowel *a*, which does not undergo Glide Formation, the stem inital vowel surfaces as short.

(7)	ba-ékite	'they laughed'
	ga-ʊ́bɩliilwe	'they (Cl. 6) are expected'
	naaba-ʊ́bɩliile	'I expected them'
	ba-óbite	'they are lost'
	a-eké	'he should laugh'
	aga-obíye	'he should lose them'

Again, the alternative analysis where one assumes the initial vowel of the stems in (6) to be underlyingly long and shortened initially or postvocalically can be ruled out by the examples in (8), where the stem has an underlying long vowel, and the vowel is long in all contexts.

(8)	áandika	'to write'	tw-áandiike	'we wrote'
	ʊʊ́ma	'to win a case'	w-ʊʊ́mite	'you won'
	ɩɩ́mba	'to dig'	ny-ɩɩ́mbite	'I dug'
	ba-ɩɩ́mbite	'they dug'		
	ba-ʊʊ́mite	'they won'		

A further tonal consideration shows that examples such as those in (5) differ from those in (8) in having underlying short vowels. In the past tense illustrated in these examples, every verb has a H tone on the first vowel of the stem: the data in (9) further illustrate this point.

(9)	tu-téliike	'we cooked'	tu-kéeŋgiimbe	'we dug tubers'
	tu-kálaaŋgite	'we fried'	tu-káatite	'we cut'

When the first vowel of the stem is long, it is realized with a falling tone, which is to say that on a long vowel, the H tone appears on the first half of the long vowel. Now notice that there is a tonal difference between those stems which begin with a long vowel and those that begin with a short vowel: the initial syllable in the first group has a falling tone while the initial syllable in the second group has a rising tone.

(10)	a.	tw-úʊmite	'we won a case'	/ʊʊm-/
		ny-úʊmite	'I won a case'	
		ba-úʊmite	'they won a case'	
	b.	tw-eékite	'we laughed'	/ek-/
		ny-eékite	'I laughed'	
		ba-ékite	'they laughed'	

When the stem initial vowel is long, it has a falling tone as expected, and that tone is not changed by the addition of a prefix, since applying Glide Formation to the prefix does not cause a change in the length of the following vowel. However, when the initial vowel is underlyingly short but becomes lengthened due to Glide Formation applying to the L toned vowel of the subject prefix, a rising tone — a long vowel whose first half is L toned and whose second half is H toned — is the result. This tonal difference would be possible only if these stems contrast in their vowel length.

There is a small complication in the operation of Glide Formation, which demonstrates the crucial connection between application of Glide Formation and compensatory lengthening of the following vowel. As can be seen in (11), when the prefix with a high vowel is not at the beginning of the word, application of Glide Formation is optional.

(11)	ku-tu-ákya	~	ku-tw-aákya	'to hunt for us'
	ku-ni-áandika	~	ku-ny-áandika	'to write me'
	a-lu-ásiime	~	a-lw-aásiime	'he borrowed it (11) (recent)'
	baa-ki-únite	~	baa-ky-uúnite	'they harvested it (7) (remote)'

These data show that the following vowel is lengthened only if Glide Formation actually applies. This rules out the possibility of stating lengthening as an independent process from Glide Formation.

In the examples of Glide Formation considered so far, the prefixal vowel and following vowel had a different quality. Data in (12) show what happens when the prefix vowel and following vowel are identical: a single long vowel results, with no glide.

(12)	k-iígé	'eyebrow'	/ki-ígé/ (Cl. 7)	(cf. ka-ígé 'little brow')
	m-uúnene	'tree'	/mu-únene/ (Cl. 3)	(cf. kaúnene 'little tree')
	l-iimyé	'slug'	/li-imyé/ (Cl. 5)	(cf. ma-imyé 'sluge')
	k-uukumú	'to Ukumu'	/ku-ukumú/ (Loc.)	(cf. ukumú 'Ukumu')

Additional data making the same point are given in (13), using the combination of a verbal prefix plus a verb stem.

(13)	niísiile	'I went'	/ni-ísiile/
	tuúnite	'we harvested'	/tu-únite/
	muúlwiike	'you (pl) descended'	/mu-úlwiike/
	nikiíyite	'I hid it (Cl.7)'	/ni-ki-íyite/
	baatuútite	'they pulled us'	/ba-a-tu-útite/

There are two ways one might approach these data. On the one hand, one might posit an independent rule which fuses sequences of identical high vowels into one long vowel; on the other hand, one might apply Glide Formation, generating forms such as *nyiísiile* and *twuúnite*, and then delete the glide by a separate rule. The specific context for deletion of a glide is when it is followed by an identical vowel.

(14) *Glide Deletion*

$$\begin{bmatrix} -\text{cons} \\ -\text{syl} \\ \alpha\text{back} \\ \beta\text{hi} \\ \gamma\text{tense} \end{bmatrix} \rightarrow \varnothing \;/\; \underline{\quad} \quad \overset{\text{V}}{\begin{bmatrix} \alpha\text{back} \\ \beta\text{hi} \\ \gamma\text{tense} \end{bmatrix}}$$

Additional data refine the Glide Deletion rule, and support the hypothesis of Glide Formation and Glide Deletion as the mechanism for handling identical vowel fusion, since these data show that the expected glide can actually be found phonetically. When the high vowel is not preceded by a consonant, deletion of the glide is optional and thus one may encounter a phonetic glide in this context.

(15)	/i-íge/	→	yiíge	~ (opt)	iíge	'eyebrows'
	/u-uúji/	→	wuúji	~ (opt)	uúji	'porridge'
	/u-úniilwe/	→	wuúniilwe	~ (opt)	uúniilwe	'it was harvested'

1.2. Tone Assignment in Verbs

Verbs in Kimatuumbi have no lexical tone contrasts; instead, tone is assigned to verbs on the basis of morphological characteristics, such as verb tense, interacting with phonological properties of the verb. In one set of verb tenses which includes the infinitive, the future tense and the subjunctive, a H tone is assigned to the first vowel of the stem. When the initial syllable contains a short vowel, this means that the vowel has a H tone, and if the initial syllable is long, this means that the vowel bears a falling tone.

(16)	ŋálaŋaata	'to shine'	káata	'to cut'
	kuki-káata	'to cut it (cl. 7)'	ki-káata	id.
	lyá	'to eat'	kuu-lyá	'to eat it (cl. 3)'
	baa-téleka	'they will cook'	baaga-téleka	'they will cook them (cl. 6)'
	ni-káatite	'I cut (rec.)'	naa-káatite	'I cut (rem.)'

This pattern makes sense if long vowels are treated phonologically as being equivalent to a sequence of identical short vowels, as they are transcribed here.

A more interesting pattern is seen in the subjunctive tense, where a H tone is assigned to the third vowel after the subject prefix. Data in (17) give uncomplicated examples of this pattern, where there are at least three vowels and none of the vowels are long.

(17)	n-teleké	'you (pl.) should cook'
	ni-kemekéme	'I should call out frequently'
	u-gundumúye	'you should scare'
	ba-tyatyakíkiyane	'they should plaster for each other'
	u-gundumúyegundumuye	'you should scare frequently'

(18) shows that if there are only one or two vowels in the verb after the subject prefix, H is assigned to the final vowel of the verb.

(18)	u-lyé	'you should eat'
	ba-temé	'they should chop'

Assignment of H tone can be handled by the following rule.

(19) *H Tone Assignment*
v → v́ / Subj. prefix + V C_0 V C_0 ___ (in the subjunctive, participial)

In case there are long vowels in the first two syllables after the subject prefix, the H tone is assigned to the third vowel as well — however, this pattern is clear only if long vowels are treated as equivalent to a sequence of short vowels, as can be seen by the parellel transcription with vowel length and contour tones being treated as atomic properties, assigned as plus or minus values of features to single vowel segments. Consider the data in (20). In the first example, the H is assigned to the first half of a long vowel, where it is phonetically interpreted as a falling tone. In the second example, the third vowel is in the second half of a long vowel, and thus the H is realized phonetically as a rising tone on a long syllable. In the third example, the H tone is realized as a level H on a short vowel in the second syllable, since the first syllable contains a long vowel, which counts as two vowels. In the final example, the H is realized on the second syllable because the preceding syllable is long which accounts for the first two vowels, and since the H is assigned to the first half of a long vowel, it is realized phonetically as a falling tone.

(20)	i-ŋalaŋáate	=	iŋalaŋâ:te	'it should shine'
	u-lɪndɪ́le	=	ulɪndɪ̌:le	'you should guard'
	u-buundáye	=	ubu:ndáye	'you should blunt'
	u-keeŋgéembe	=	uke:ŋgê:mbe	'you should dig tubers'

The description of this pattern is incoherent, unless one assumes that long vowels are really sequences of identical vowels and rising and falling tones are really LH versus HL sequences of tones on identical vowels.

In the examples presented above, the three-vowel sequence was contained entirely within the stem. However, an object prefix may appear after the subject prefix, and the vowel of that prefix will be included in the count, so that after an object prefix, the H tone appears on the second vowel of the stem — where it may be realized phonetically as a rising tone if it lands on the second half of a long vowel, or as a falling tone if it lands on the first half of a long vowel.

(21)	u-ki-lyé	'you should eat it (Cl. 7)'
	mu-u-temé	'you (pl) should chop it (Cl. 3)'
	mu-u-teméteme	'you (pl) should chop it (Cl. 3) often'
	ba-ni-teléki	'they should cook for me'
	u-ki-buúndaye	'you should blunt it (Cl. 7)'
	u-ni-kaláaŋgi	'you should fry for me'

Similarly, the aspect prefixes -*ka*- and -*a*- can appear after the subject prefix, and they too are included in the count of vowels after the subject prefix.

(22)	ni-ka-kaláaŋge	'I should go fry'
	u-ka-gundúmuye	'you should go scare'
	w-aa-lɪndɪ́ɪle	'you should guard (fut)'
	w-aa-buúndaye	'you should blunt (fut)'

Finally, when the verb contains both an aspect prefix and an object prefix, the H tone is assigned to the first vowel of the stem — again, the H is assigned consistently to the third vowel after the subject prefix.

(23)	ni-ka-u-kúŋuunde	'I should go filter it (Cl. 14)'
	ba-ka-t-úundwe	'they should go untie us'
	w-aa-ni-lɪ́ndɪɪle	'you should guard me (fut.)'

This pattern of tone assignment is also found in the participial tense, as can be seen in (24). The examples in (a) show that H is assigned to the final vowel if the verb has only one or two vowels after the subject prefix; those in (b) show straightforward assignment of H to the third vowel; (c) shows how the assignment of tone is based on a phonological decomposition of long vowels into a sequence of two short vowels; (d) shows that the object prefix is also included in the count of vowels. These are exactly the patterns which were encountered in the subjunctive tense.

(24)	a.	ka-ni-lyá	'while I was eating'
		ka-ni-temá	'while I was chopping'
	b.	ka-ba-teleká	'while they were cooking'
		ka-ni-tematéma	'while I was chopping frequently'
	c.	ka-tu-lɪndɪ́ɪla	'while we were waiting'
		ka-i-ŋalaŋáata	'while it was shining'
		ka-ni-buundáya	'while I was blunting'
	d.	ka-ny-uu-temá	'while I was chopping it (Cl. 3)'
		ka-ba-ku-telékya	'while they were cooking for you'
		ka-ni-ku-gundúmuya	'while I was scaring you'

There is an interesting complication to the pattern of tone assignment, where the H surfaces on the second vowel and not the third vowel. Just in case the verb has a long vowel in the penultimate syllable and the tone would have been assigned to the final syllable, H actually is realized on the penult, as a rising tone.

(25)	u-kaáte	'you should cut'	*u-kaaté
	u-toóle	'you should take'	*u-toolé
	kani-kaáta	'while I was taking'	*kani-kaatá

This apparent exception can be explained by assigning H to the third vowel, as expected, and then applying a rule which retracts H tone from a final syllable to the second half of a preceding long syllable.

(26) *H Tone Retraction*
vv c v́ # → vv́ c v #

In certain other verb tenses, a H tone is assigned to the second vowel of a stem, which includes the vowel of any object prefix. Examples of this pattern are seen in (27) using the 'when-habitual' tense. Here too, the pattern of tone assignment provides evidence for treating long vowels as a sequence of identical vowels, so that if the first vowel is long the H is realized on the first syllable as a rising tone, and if the first vowel is short and the second long, the H is realised on the second syllable with a falling tone.

(27)	patú-lyá	'when we eat'
	paá-ki-lyá	'when he eats it (Cl. 7)'
	paá-temá	'when he chops'
	pabá-kunákuna	'when they grated coconuts frequently'
	paá-ki-téma	'when he chops it (Cl. 7)'
	paní-kaáta	'when I cut'
	paá-ni-káatya	'when he cuts for me'
	paú-lɪndúɪla	'when you guard'
	paá-ki-líndɪɪla	'when he guards it (Cl. 7)'

This same pattern is found in the relative clause habitual tense and the habitual.

(28)	ywaá-teléka	'the one who cooks'
	ywaá-kutélekya	'the one who cooks for you'
	ywaá-kaáta	'the one who cuts'
	ywaá-lɪndúɪla	'the one who waits'
	baká-teléka	'if they cook'
	baká-kutélekya	'if they cook for you'
	tuká-goónja	'if we sleep'

1.3. Phrasal Shortening

There is a general rule in Kimatuumbi that when a word is followed by a modifier in its phrase, long vowels in the first word are shortened. Examples of this can be seen in (29), where the noun in its citation form has a long vowel, but when it is followed by a modifier such as a possessive pronoun, an adjective, a relative clause or a determiner, the long vowel is shortened.

(29)	kikóloombe	'cleaning shell'
	kikólombe čaáŋgʊ	'my cleaning shell'
	mikaáte	'loaves'
	mikaté mikólʊ mikólʊ́	'large loaves'
	lukaámba	'string'
	lukambá lwalúpʊwáaniiké	'string which broke'
	mboópo	'machete'
	mbopó ye	'the machete'

The syntactic relation between the word that undergoes shortening and the following word is crucial. If the two words are not in the head-modifier relation, then there is no vowel shortening.

(30) [$_{NP}$ kikóloombé[1] $_{NP}$] [$_{VP}$ čaapʊ́waaniike $_{VP}$]
shell broken

'The shell is broken'

[$_{VP}$ naampéi [$_{NP}$ kikóloombe $_{NP}$] [$_{NP}$ Mambóondo $_{NP}$] $_{VP}$]
I-him-gave shell Mamboondo

'I gave Mamboondo the shell'

[$_{VP}$ naakibwéni [$_{NP}$ kikóloombe $_{NP}$] ĺiilí $_{VP}$]
I-it-saw shell neg

'I didn't see the shell'

This rule also applies to verbs, when they are followed by objects or any other word.

(31)	nika-kálaaŋga	'I will go fry'
	nika-kálaŋga ĺí	'I will not go fry'
	nika-kálaŋga kinjáambú	'I will go fry cassava'
	nika-kálaŋga yóopáta eéla	'I will go fry to get money'

We will formalize this process as follows, forgoing a detailed account of how the syntactic conditions are to be imposed on this rule.

(32) *Phrasal Shortening*
VV → V / __ ... # X

[1] The word-final H tone is assigned by a rule which will not be considered here.

1.4. Interaction between processes

Now we turn to the interaction between the phonological processes motivated above. Recall that there is a rule retracting a H tone from a final syllable to an immediately preceding long penult, so that where one would have expected (on analogy to *uteleké*) that the subjunctive form should be **ukoomwé* because the final vowel is the third vowel, the actual form is *ukoómwe*. However, a long vowel which is derived by the compensatory lengthening side effect of Glide Formation does not trigger this tone retraction process.

(33)	áka	'to hunt'	waaké	'you should hunt'
	éka	'to laugh'	weeké	'you should laugh'
	íya	'to hide something'	wiiyé	'you should hide'

We can explain these examples by assuming that Glide Formation applies after H Tone Retraction. At the stage where H Tone Retraction applies, the verb *waaké* has the form *u-aké*, which has no long vowel, and therefore Retraction cannot apply. Latter application of Glide formation yields *waaké*: the opportunity to apply Tone Retraction has passed by.

Contrasting with stems of the form VCV such as *-ake* are stems of the form VVCV, such as *-aame*. In such stems which have an underlying long vowel, Glide Formation is not needed to create a long vowel that triggers Retraction, and as the following data show, Retraction does apply to the H which is expected to be on the final syllable.

(34)	áama	'to emigrate'	waáme 'you should emigrate'
	ɪ́mba	'to dig'	wɪ́mbe 'you should dig'

Thus, underlying /u-aamé/ undergoes Retraction to give *uaáme*, which then undergoes Glide Formation resulting in surface *waáme*.

Another process which affects vowel length is Phrasal Shortening. The examples in (35) are nouns which have an underlying final H tone that is preceded by a penultimate long syllable. When the noun stands alone, the long vowel is unaffected, and the final H tone is retracted, thus /mboopó/ → [mboópo] 'machete'. When the noun is followed by a modifier, the vowel is shortened, and therefore the H tone remains in its underlying position, on the final syllable.

(35)	mboópo	'machete'	mbopó yaáŋgʊ	'my machete'
	kalataási	'paper'	kalatasí ŋgʊlʊ́	'large piece of paper'
	sipitaáli	'hospital'	sipitalí yɪnó	'this hospital'
	ŋkaáte	'loaf'	ŋkatée mmígí	'raw loaf of bread'

A related point can be made with verbs in the subjunctive tense; when the verb stands alone, the vowel remains long so Retraction shifts the final H to the penult, whereas if the verb is followed by a modifier, the vowel is shortened, so there is no retraction.

(36)	ubeénde	'you should shout'
	ubendé ukumú	'you should shout at Ukumu'
	ukoómwe	'you should cough'
	ukomwé lí	'you should not cough'

These data demonstrate that Phrasal Shortening precedes Retraction, since application of Shortening crucially deprives words of the long vowel required by Retraction. We have also seen that Retraction precedes Glide Formation, giving the strict ordering Shortening → Retraction → Glide Formation. The interaction between all three of these processes can be directly investigated, by considering words composed of prefix plus VCV and VVCV stem having a final H tone, followed by a modifier. First we consider stems with underlying short vowels. As seen in (37), such stems retain long surface vowels, and their final H does not alternate in position.

(37)	ly-oowá	'beehive'	ly-oowá linaántopá	'heavy beehive'
	lw-aaté	'banana hand'	lw-aaté lwaáŋgʊ	'my banana hand'
	w-iiyé	'you should hide'	w-iiyé kitéleéko	'you should hide the pot'

Starting from underlying /u-iyé kitéleéko/, Shortening is not applicable because the verb has no long vowels. Retraction would be the next rule applicable, but final H does not retract because the preceding vowel has not become long yet. Finally, Glide Formation applies to give the surface form: at this point the conditions for Retraction and Shortening are found, but the opportunity to apply those rules have already passed.

On the other hand, if the word has the underlying stem shape VVCV, the conditions for H Tone Retraction are satisfied without application of Glide Formation. Thus, such nouns exhibit an alternation in the position of tone depending on phrasal position, but do not have an alternation in vowel length.

(38)	mw-eémbe	'mango tree'
	mw-eembé waáŋgʊ	'my mango tree'
	ky-ɩímbe	'knife'
	ky-ɩmbé činaántopá	'heavy knife'

In its isolation form, the noun *mweémbe* is underlying *mu-eembé*; it undergoes Retraction because of the long vowel, then Glide Formation applies, which has no effect on surface vowel length because the initial vowel is already long. In the

phrase *mweembé waáŋgu*, the underlying form first undergoes Shortening, giving *muembé waáŋgu*. Retraction cannot apply to this because it has a short vowel in the penult, and therefore the tone remains on the last syllable. Subsequently, Glide Formation applies, giving the phonetic form.

To summarize, the following N rules have been motivated for Kimatuumbi, along with their crucial orderings.

(39)

Phrasal Shortening

$$VV \rightarrow V \;/\; \_\_ \ldots \# \; X$$

H Tone Assignment

$$v \rightarrow \acute{v} \;/\; \text{Subj. prefix} + V\, C_0\, V\, C_0 \_\_\_ \quad \text{(subjunctive, participial)}$$

H Tone Retraction

$$vv\, c\, \acute{v}\, \# \rightarrow v\acute{v}\, c\, v\, \#$$

Glide Formation

$$\overset{V}{[+hi]} \rightarrow [-syl] \;/\; \_\_\, V$$

Glide Deletion

$$\begin{bmatrix} -cons \\ -syl \\ \alpha back \\ \beta hi \\ \gamma tense \end{bmatrix} \rightarrow \varnothing \;/\; \_\_\_ \; \overset{V}{\begin{bmatrix} \alpha back \\ \beta hi \\ \gamma tense \end{bmatrix}}$$

2. Syrian Arabic

In this section, the core phonological processes of Syrian Arabic (Damascus dialect) are investigated, focusing on the alternations which arise in the inflectional paradigm of the verb. One of the central problems which pervades the phonology is the issue of the underlying representation of vowels. It will be seen that vowels have a somewhat abstract representation, so that underlying /i,u/ frequently become [e,o], [ə] or is deleted, and often does not actually surface as [i,u].

2.1. Preliminary on morphological structure

Verb roots in Arabic are traditionally analysed as being composed of consonants only. Vowels appear on the surface due to what is known as ‘templatic morphology’, where the typical underlying stem shape is of the form CVCVC in

the perfective aspect, and CCVC in the imperfective. The particular vowel used in the perfective versus the imperfective is specified lexically, so some verbs use *a* in the perfective and *o* in the imperfective (*katab* perf. -*ktob* impf. 'write'), while others use *a* in the perfective and *e* in the imperfective (*ħamal* perf. -*ħmel* impf. 'carry'), and others use *e* in the perfective and *a* in the imperfective (*ʔəbel* perf. *ʔbal* impf 'be able'). The imperfective stem can be used with subject suffixes to form the imperative, or with subject prefixes and suffixes to form the imperfective subjunctive. An additional prefix, *b*-, is used in indicative imperfective clauses. The subject marking prefixes and suffixes are as follows.

(40)

	perf.	*imperf. subjunctive*	*imperative*
3m	∅	yə-	
3f	-et	tə-	
3p	-u	yə- -u	
2m	-t	tə-	∅
2f	-ti	tə- -i	-i
2p	-tu	tə- -u	-u
1s	-t	ə-	
1p	-na	nə-	

The underlying vowel patterns used are the following (where the first vowel is the vowel of the perfective and the second vowel is the vowel of the imperfective): *a*/*u, a*/*i, a*/*a, i*/*i, i*/*a*. Often, the high vowels are phonetically realized as [e], [o] or [ə], by rules to be discussed.

2.2. Basic CVCVC verbs

We begin our investigation by looking at the phonology of verb stems which select *a* in both the perfective and the imperfective. The data in (41) are examples of verb stems which select this vowel pattern.

(41)

	'ask'			'shut'		
	perf.	impf. ind.	impf. sbj	perf.	impf. ind.	impf. sbj
3m	sáʔal	byə́sʔal	yə́sʔal	fátaħ	byə́ftaħ	yə́ftaħ
3f	sáʔlet	btə́sʔal	tə́sʔal	fátħet	btə́ftaħ	tə́ftaħ
3p	sáʔalu	byə́sʔalu	yə́sʔalu	fátaħu	byə́ftaħu	yə́ftaħu
2m	saʔálət	btə́sʔal	tə́sʔal	fatáħət	btə́ftaħ	tə́ftaħ
2f	saʔálti	btə́sʔali	tə́sʔali	fatáħti	btə́ftaħi	tə́ftaħi
2p	saʔáltu	btə́sʔalu	tə́sʔalu	fatáħtu	btə́ftaħu	tə́ftaħu
1s	saʔálət	bə́sʔal	ʔə́sʔal	fatáħət	bə́ftaħ	ʔə́ftaħ
1p	saʔálna	mnə́sʔal	nə́sʔal	fatáħna	mnə́ftaħ	nə́ftaħ
imp	sʔá:l, sʔáli, sʔálu			ftá:ħ, ftáħi, ftáħu		
(masc sg, fem sg, pl)						

	'send'			'keep'		
	perf.	impf. ind.	impf. sbj	perf.	impf. ind.	impf. sbj
3m	báʕat	byə́bʕat	yə́bʕat	ħáfaẓ	byə́ħfaẓ	yə́ħfaẓ
3f	báʕtet	btə́bʕat	tə́bʕat	ħáfẓet	btə́ħfaẓ	tə́ħfaẓ
3p	báʕatu	byə́bʕatu	yə́bʕatu	ħáfaẓu	byə́ħfaẓu	yə́ħfaẓu
2m	baʕátət	btə́bʕat	tə́bʕat	ħafáẓət	btə́ħfaẓ	tə́ħfaẓ
2f	baʕátti	btə́bʕati	tə́bʕati	ħafáẓti	btə́ħfaẓi	tə́ħfaẓi
2p	baʕáttu	btə́bʕatu	tə́bʕatu	ħafáẓtu	btə́ħfaẓu	tə́ħfaẓu
1s	baʕátət	bə́bʕat	ʔə́bʕat	ħafáẓət	bə́ħfaẓ	ʔə́ħfaẓ
1p	baʕátna	mnə́bʕat	nə́bʕat	ħafáẓna	mnə́ħfaẓ	nə́ħfaẓ
imp	bʕá:t, bʕáti, bʕátu			ħfá:ẓ, ħfáẓi, ħfáẓu		

We start with the perfective forms, which are the simplest. Apart from assignment of stress, the only alternation found in that tense is the deletion of the second stem vowel *a* before the 3f subject suffix -*et*, where for example /saʔal-et/ → [saʔlet]. The context where this vowel is deleted — VC__CV — is the classical context for vowel syncope, however, it must be noted that the parallel form *saʔalu* does not undergo Syncope. At this point, we will propose a rule of Syncope, and await further data before explaining exactly where the rule applies.

(42) *Syncope*
a → ∅ / VC __ Ce

As far as stress assignment is concerned, stress in these examples is assigned either to the penultimate or antepenultimate syllable, depending on the suffix which follows. Stress generally falls on the penult in these examples, including when there is no affix, when the following affix is of the form -CV, and also before the suffix -*et*, but is on the antepenult before the 3p suffix -*u*. Further data will be required to make the principles of stress assignment clearer.

The imperfective inflection is fairly simple. There are a number of ways to state the generalization regarding stress for these forms. One generalization is that stress appears on the penultimate or antepenultimate syllables, depending on whether a vowel initial affix is added as was the case for perfective verbs; another generalization is that stress in the imperfective is word initial. Since stress is not generally word initial (cf. *saʔáltu*), we will not pursue the second observation further, but will await further data to make clear what the stress pattern is.

There is an alternation in the form of the indicative prefix *b*-, which surfaces as *m*- before the 1p imperfective prefix *nə*. This is transparently an assimilation of nasality, which can be accounted for by the following rule.

(43) *Nasalization*
b → [+nasal] / __ [+nasal]

Another alternation occurs with a 1s subject. In the subjunctive, the prefix surfaces as *ʔə* (*ʔə́sʔal*), but there is no glottal stop in the indicative following *b-* (*bə́sʔal*). One analysis would be that the prefix is underlyingly /ə/ and glottal stop is inserted before an initial vowel. Or, the prefix could be /ʔə/ and glottal stop deletes after a consonant. This will not work, given examples such as imperfective *btə́sʔal* and imperative *sʔá:l* where postconsonantal glottal stop survives. Therefore, we assume that the prefix is underlyingly /ə/ and posit the following rule.

(44) *Glottal Prothesis*
∅ → ʔ / # ___ V

The last alternation which can be seen in this paradigm are found in the imperative. In the singular imperative, where no suffix is added, the stem vowel *a* is lengthened to *a:*. This is due to a restriction on the minimum allowed size of a word: **sʔal* is too short a word in Syrian Arabic, and therefore the vowel must be lengthened. The exact conditions on the minimal word will be discussed in detail as more data becomes available, but roughly, the smallest word must contain two vowels (including one long vowel), or else one vowel followed by two consonants. The following rule will account for this lengthening in the singular imperative.

(45) *Lengthening*
V → VV / #C_0 __ C#

We next turn to verbs which select *a* as the stem vowel in the perfective and /u/ in the imperfective — although it will take more analysis to justify the claim that the vowel of the imperfective is actually *u* underlyingly, since on the surface the vowel surfaces as *o* in most contexts, and at this point we could just assume that the underlying vowel is /o/.

(46)

	'write'			'command'		
	perf.	impf. ind.	impf. sbj	perf.	impf. ind.	impf. sbj
3m	kátab	byə́ktob	yə́ktob	ʔámar	byə́ʔmor	yə́ʔmor
3f	kátbet	btə́ktob	tə́ktob	ʔámret	btə́ʔmor	tə́ʔmor
3p	kátabu	byə́kətbu	yə́kətbu	ʔámaru	byə́ʔəmru	yə́ʔəmru
2m	katábət	btə́ktob	tə́ktob	ʔamárət	btə́ʔmor	tə́ʔmor
2f	katábti	btə́kətbi	tə́kətbi	ʔamárti	btə́ʔəmri	tə́ʔəmri
2p	katábtu	btə́kətbu	tə́kətbu	ʔamártu	btə́ʔəmru	tə́ʔəmru
1s	katábət	bə́ktob	ʔə́ktob	ʔamárət	bə́ʔmor	ʔə́ʔmor
1p	katábna	mnə́ktob	nə́ktob	ʔamárna	mnə́ʔmor	nə́ʔmor
imp	któ:b, ktə́bi, ktə́bu			ʔmó:r, ʔmə́ri, ʔmə́ru		

	'study'			'cook'		
	perf.	impf. ind.	impf. sbj	perf.	impf. ind.	impf. sbj
3m	dáras	byə́dros	yə́dros	ṭábax	byə́ṭbox	yə́ṭbox
3f	dárset	btə́dros	tə́dros	ṭábxet	btə́ṭbox	tə́ṭbox
3p	dárasu	byə́dərsu	yə́dərsu	ṭábaxu	byə́ṭəbxu	yə́ṭəbxu
2m	darásət	btə́dros	tə́dros	ṭabáxət	btə́ṭbox	tə́ṭbox
2f	darásti	btə́dərsi	tə́dərsi	ṭabáxti	btə́ṭəbxi	tə́ṭəbxi
2p	darástu	btə́dərsu	tə́dərsu	ṭabáxtu	btə́ṭəbxu	tə́ṭəbxu
1s	darásət	bə́dros	ʔə́dros	ṭabáxət	bə́ṭbox	ʔə́ṭbox
1p	darásna	mnə́dros	nə́dros	ṭabáxna	mnə́ṭbox	nə́ṭbox
imp	dró:s, drə́si, drə́su			ṭbó:x, ṭbə́xi, ṭbə́xu		

The perfective form of the verb stems in (46) work exactly like those in (41): the stem vowel is deleted before the suffix *-et*, and stress alternates between the penult and the antepenult.

Turning then to the imperfective forms of the verb, the stem has a different underlying phonological shape, namely CCoC (or CCuC). There is an alternation within these verbs between CCoC and CəCC, the latter appearing when a vowel initial affix follows the stem. One might posit a rather complex rule which changes the quality of the stem vowel and moves it between the first two stem consonants, but a better analysis would decompose this alternation into two simple operations. We will assume that the stem vowel is first deleted, so that underlying /byəktobu/ becomes *byəktbu*, and then exploit the fact that there are no clusters of three consecutive consonants in the language, which allows us to posit a rule of vowel epenthesis inserting schwa after the first of three consecutive consonants. Since we have not fully resolved the issue of Syncope in the perfective tense, we cannot yet determine whether the vowel deletion rule found in the imperfective data is the same rule as seen in the perfective forms. If indeed this vowel deletion were governed by the same rule, then the context could not be more specific than a following -V suffix, since the lefthand contexts where deletion takes place differ considerably, including just VC in the perfective but including VCC in the imperfective. We will therefore leave this issue unresolved temporarily, but eventually we will see that there must be two rules of vowel deletion. Epenthesis of schwa, on the other hand, poses no problems and can be accounted for by the following rule.

(47) *Epenthesis*
$\varnothing \rightarrow$ ə / C __ CC

There is one further difference between these verbs and the verbs with /a/ in the imperfective. In the imperative, when a vowel initial suffix is added, there is no vowel lengthening, and instead the vowel *o* becomes schwa, thus /ktob-i/ $\rightarrow$ *ktə́bi*. Once more data is available, it will be seen that this is a reflection of the restricted

distribution of the vowel *o* (also *e*) in the language, which appears only in the last syllable of a word. We will therefore tenatively assume the following rule.

(48) *Mid vowel reduction*
e,o → ə / __ C_0 V

At this point, we turn to another class of verbs of the form CVCVC, this time verbs with the vowel *a* in the perfective and /i/ in the imperfective — on the surface, the perfective vowel is [e] alternating with schwa.

(49)

	'carry'			'divide'		
	perf.	impf. ind.	impf. sbj	perf.	impf. ind.	impf. sbj
3m	ħámal	byə́ħmel	yə́ħmel	ʔásam	byə́ʔsem	yə́ʔsem
3f	ħámlet	btə́ħmel	tə́ħmel	ʔásmet	btə́ʔsem	tə́ʔsem
3p	ħámalu	byə́ħəmlu	yə́ħəmlu	ʔásamu	byə́ʔəsmu	yə́ʔəsmu
2m	ħamálət	btə́ħmel	tə́ħmel	ʔasámət	btə́ʔsem	tə́ʔsem
2f	ħamálti	btə́ħəmli	tə́ħəmli	ʔasámti	btə́ʔəsmi	tə́ʔəsmi
2p	ħamáltu	btə́ħəmlu	tə́ħəmlu	ʔasámtu	btə́ʔəsmu	tə́ʔəsmu
1s	ħamálət	bə́ħmel	ʔə́ħmel	ʔasámət	bə́ʔsem	ʔə́ʔsem
1p	ħamálna	mnə́ħmel	nə́ħmel	ʔasámna	mnə́ʔsem	nə́ʔsem
imp	ħmé:l, ħmə́li, ħmə́lu			ʔsé:m, ʔsə́mi, ʔsə́mu		

	'wash'			'grasp'		
	perf.	impf. ind.	impf. sbj	perf.	impf. ind.	impf. sbj
3m	γásal	byə́γsel	yə́γsel	kámaš	byə́kmeš	yə́kmeš
3f	γáslet	btə́γsel	tə́γsel	kámšet	btə́kmeš	tə́kmeš
3p	γásalu	byə́γəslu	yə́γəslu	kámašu	byə́kəmšu	yə́kəmšu
2m	γasálət	btə́γsel	tə́γsel	kamášət	btə́kmeš	tə́kmeš
2f	γasálti	btə́γəsli	tə́γəsli	kamášti	btə́kəmši	tə́kəmši
2p	γasáltu	btə́γəslu	tə́γəslu	kamáštu	btə́kəmšu	tə́kəmšu
1s	γasálət	bə́γsel	ʔə́γsel	kamášət	bə́kmeš	ʔə́kmeš
1p	γasálna	mnə́γsel	nə́γsel	kamášna	mnə́kmeš	nə́kmeš
imp	γsé:l, γsə́li, γsə́lu			kmé:š, kmə́ši, kmə́šu		

Inspection of these data shows that this set of verbs is essentially identical to the previous set of examples, and differs only in that the vowel in the imperfective is [e] and not [o]; otherwise, the two sets of data are the same.

We now come to a fourth group of verbs, which select underlying /i/ in both the perfective and imperfective — again, we could also assume at this point that the vowel is underlying /e/. The phonology of this class of verbs in the imperfective is identical to that of the immediately preceding set, and thus requires no additional comment. The vocalic pattern of the verb in the perfective, on the other hand, is more complex.

(50)

	'descend'			'hold'		
	perf.	impf. ind.	impf. sbj	perf.	impf. ind.	impf. sbj
3m	nə́zel	byə́nzel	yə́nzel	mə́sek	byə́msek	yə́msek
3f	nə́zlet	btə́nzel	tə́nzel	mə́sket	btə́msek	tə́msek
3p	nə́zlu	byə́nəzlu	yə́nəzlu	mə́sku	byə́məsku	yə́məsku
2m	nzə́lət	btə́nzel	tə́nzel	msə́kət	btə́msek	tə́msek
2f	nzə́ltu	btə́nəzli	tə́nəzli	msə́ktu	btə́məski	tə́məski
2p	nzə́lti	btə́nəzlu	tə́nəzlu	msə́kti	btə́məsku	tə́məsku
1s	nzə́lət	bə́nzel	ʔə́nzel	msə́kət	bə́msek	ʔə́msek
1p	nzə́lna	mnə́nzel	nə́nzel	msə́kna	mnə́msek	nə́msek
imp	nzé:l, nzə́li, nzə́lu			msé:k, msə́ki, msə́ku		

	'dress'			'be able'		
	perf.	impf. ind.	impf. sbj	perf.	impf. ind.	impf. sbj
3m	lə́bes	byə́lbes	yə́lbes	ʔə́der	byə́ʔder	yə́ʔder
3f	lə́bset	btə́lbes	tə́lbes	ʔə́dret	btə́ʔder	tə́ʔder
3p	lə́bsu	byə́ləbsu	yə́ləbsu	ʔə́dru	byə́ʔədru	yə́ʔədru
2m	lbə́sət	btə́lbes	tə́lbes	ʔdə́rət	btə́ʔder	tə́ʔder
2f	lbə́stu	btə́ləbsi	tə́ləbsi	ʔdə́rtu	btə́ʔədri	tə́ʔədri
2p	lbə́sti	btə́ləbsu	tə́ləbsu	ʔdə́rti	btə́ʔədru	tə́ʔədru
1s	lbə́sət	bə́lbes	ʔə́lbes	ʔdə́rət	bə́ʔder	ʔə́ʔder
1p	lbə́sna	mnə́lbes	nə́lbes	ʔdə́rna	mnə́ʔder	nə́ʔder
imp	lbé:s, lbə́si, lbə́su			ʔdé:r, ʔdə́ri, ʔdə́ru		

Let us compare the perfective forms of /katab/ 'write' with /nizil/ 'descend' to see where the differences lie.

(51)

3m	nə́zel	kátab
3f	nə́zlet	kátbet
3p	nə́zlu	kátabu
2m	nzə́lət	katábət
2f	nzə́ltu	katábti
2p	nzə́lti	katábtu
1s	nzə́lət	katábət
1p	nzə́lna	katábna

In the case of stems with /a/ in the perfective, it is obvious that the stem has the underlying shape CaCaC, since there is only one context where the stem is different. For stems such as 'descend', it is not so obvious what the underlying stem is, since the stem varies on the surface between CəCeC, CəCC and CCəC. We will begin with the alternation in the final vowel between *e* and *ə*, since that is the most straightforward. It has been observed above that *e* (and *o*) only appears in the final

syllable of a word, and that there is a rule reducing the mid vowels to schwa in a nonfinal syllable. Application of this rule accounts for the second stem syllable in examples such as *nzə́ltu* from *nəzéltu* where *e* appears as schwa.

Now we consider the issue of the V ~ ∅ alternation. Both of the stem vowels are subject to deletion in some context, cf. *nə́zel* ~ *nə́zlu*, and *nə́zel* ~ *nzə́ltu*. Let us assume that both vowels are underlyingly present, and are subject to deletion in some context. Therefore, prior to deletion of the vowel, the perfective forms of 'descend' would be as follows.

(52)	3m	nə́zel	3f	nə́zəl-et
	3p	nə́zəl-u	2m	nəzə́l-ət
	2f	nəzə́l-tu	2p	nəzə́l-ti
	1s	nəzə́l-ət	1p	nəzə́l-na

The generalization regarding retention of the vowel schwa is now clear: it is deleted if it is unstressed and in an open syllable, otherwise it is retained. At this point we have no clear evidence whether the vowel that is deleted has the quality *e* or *ə*, and we will formalize our rule generally so that it would not matter what the underlying vowel quality is.

(53) *Nonlow vowel deletion*

$$\overset{\text{V}}{\begin{bmatrix}\text{-stress}\\ \text{-low}\end{bmatrix}} \rightarrow \varnothing \,/\, \_\_\,\text{CV}$$

These data help to clarify an aspect of the phonology of imperfective verbs noted above. It was observed, in discussing stems such as *katab* ~ *ktob*, that there is a V ~ ∅ alternation in the perfective; at that point it was not clear whether that alternation was due to the same rule as the one which accounts for /katabet/ → *katbet*. We can now see that these must be due to separate rules. Clearly, the deletion of unstressed nonlow vowels in open syllables cannot be generalized to include low vowels, as shown by the many forms where unstressed /a/ does not delete in an open syllable, such as 3p perfective *sáʔalu*, imperfective *byə́sʔalu*, 2m perfective *saʔáləṭ*. We may now conclude that the ∅ alternant in the imperfective is in fact due to this rule specifically targetting nonlow vowels, and not some generalized syncope rule affecting all vowels.

Now we have a rule which accounts for the V ~ ∅ alternation of stems like *nəzel*, and a rule which accounts for the *e* ~ *ə* alternation. The two most obvious choices regarding the underlying form of the stem are *nəzel* and *nezel* (another possibility is /nizil/, but at this point there is little reason to assume that underlying form). The advantage to assuming /nəzel/ is that it is fairly non-abstract: the underlying vowel is actually attested in some surface form. On the other hand, assuming

/nezel/ allows us to express another generalization regarding vowels: within a stem type, there is only a single underlying vowel. Further data may clarify whether either of these assumptions has an empirical advantage.

Since we understand the vocalic alternations in perfective stems with /e/, we can present examples of stems with *e* in the perfective and *a* in the imperfective, which is the last class of vocalic patterns.

(54)

	'accept'			'understand'		
	perf.	impf. ind.	impf. sbj	perf.	impf. ind.	impf. sbj
3m	ʔə́bel	byə́ʔbal	yə́ʔbal	fə́hem	byə́fham	yə́fham
3f	ʔə́blet	btə́ʔbal	tə́ʔbal	fə́hmet	btə́fham	tə́fham
3p	ʔə́blu	byə́ʔbalu	yə́ʔbalu	fə́hmu	byə́fhamu	yə́fhamu
2m	ʔbə́lət	btə́ʔbal	tə́ʔbal	fhə́mət	btə́fham	tə́fham
2f	ʔbə́lti	btə́ʔbali	tə́ʔbali	fhə́mti	btə́fhami	tə́fhami
2p	ʔbə́ltu	btə́ʔbalu	tə́ʔbalu	fhə́mtu	btə́fhamu	tə́fhamu
1s	ʔbə́lət	bə́ʔbal	ʔə́ʔbal	fhə́mət	bə́fham	ʔə́fham
1p	ʔbə́lna	mnə́ʔbal	nə́ʔbal	fhə́mna	mnə́fham	nə́fham
imp	ʔbá:l, ʔbáli, ʔbálu			fhá:m, fhámi, fhámu		

The phonology of these stems is totally predictable at this point: the perfective works like /nizil/ so both vowels are subject to deletion, and the imperfective works like /saʔal/, so the stem vowel is not deleted.

2.3. Glide Initial CVCVC stems

In the data considered in the previous section, the nature of the root consonants did not make any difference to the phonology of the verb. However, stems with glides act different from other kinds of stems. In this section we concentrate on stems whose initial consonant is a glide, primarily /w/, since those stems have a different phonological pattern.

We will begin with verbs with *a* in both tenses; examples are given in (55).

(55)

	'place'			'entrust'		
	perf.	impf. ind.	impf. sbj	perf.	impf. ind.	impf. sbj
3m	wáḍaʕ	byú:ḍaʕ	yú:ḍaʕ	wádaʕ	byú:daʕ	yú:daʕ
3f	wáḍʕet	btú:ḍaʕ	tú:ḍaʕ	wádʕet	btú:daʕ	tú:daʕ
3p	wáḍaʕu	byú:daʕu	yú:daʕu	wádaʕu	byú:daʕu	yú:daʕu
2m	waḍáʕət	btú:ḍaʕ	tú:ḍaʕ	wadáʕət	btú:daʕ	tú:daʕ
2f	waḍáʕti	btú:ḍaʕi	tú:ḍaʕi	wadáʕti	btú:daʕi	tú:daʕi
2p	waḍáʕtu	btú:ḍaʕu	tú:ḍaʕu	wadáʕtu	btú:daʕu	tú:daʕu
1s	waḍáʕət	bú:ḍaʕ	ʔú:ḍaʕ	wadáʕət	bú:daʕ	ʔú:daʕ
1p	waḍáʕna	mnú:ḍaʕ	nú:ḍaʕ	wadáʕna	mnú:daʕ	nú:daʕ
imp	wḍa:ʕ, wḍaʕi, wḍaʕu			wda:ʕ, wdaʕi, wdaʕu		

The perfective inflection poses no problem. However, the imperfective of a w-initial root differs radically from the phonology of a root beginning with another consonant. Parallel examples from the subjunctive are given in (56).

(56)

	'place'	'ask'
3m	y-ú:ḍaʕ	yə́-sʔal
3f	t-ú:ḍaʕ	tə́-sʔal
3p	y-ú:daʕu	yə́-sʔalu
2m	t-ú:ḍaʕ	tə́-sʔal
2f	t-ú:ḍaʕi	tə́-sʔali
2p	t-ú:ḍaʕu	tə́-sʔalu
1s	ʔ-ú:ḍaʕ	ʔə́-sʔal
1p	n-ú:ḍaʕ	nə́-sʔal

Parallel to 'ask', we would have expected forms such as the following.

(57)

3m	*yə́wḍaʕ	3f	*tə́wḍaʕ
3p	*yə́wdaʕu	2m	*tə́wḍaʕ
2f	*tə́wḍaʕi	2p	*tə́wḍaʕu
1s	*ʔə́wḍaʕ	1p	*nə́wḍaʕ

The actual surface forms are accounted for by a glide-vocalization rule.

(58) *Glide Vocalization*
ə w C → u: C

Given this simple rule, we can now consider other vowel patterns among verb roots beginning with a glide. A number of such verbs have *a* in the perfective and *e* (/i/) in the imperfective.

(59)

	'describe'			'promise'		
	perf.	impf. ind.	impf. sbj	perf.	impf. ind.	impf. sbj
3m	wáṣaf	byú:ṣef	yú:ṣef	wáʕad	byú:ʕed	yú:ʕed
3f	wáṣfet	btú:ṣef	tú:ṣef	wáʕdet	btú:ʕed	tú:ʕed
3p	wáṣafu	byú:ṣfu	yú:ṣfu	wáʕadu	byú:ʕdu	yú:ʕdu
2m	waṣáfət	btú:ṣef	tú:ṣef	waʕádət	btú:ʕed	tú:ʕed
2f	waṣáfti	btú:ṣfi	tú:ṣfi	waʕádti	btú:ʕdi	tú:ʕdi
2p	waṣáftu	btú:ṣfu	tú:ṣfu	waʕádtu	btú:ʕdu	tú:ʕdu
1s	waṣáfət	bú:ṣef	ʔú:ṣef	waʕádət	bú:ʕed	ʔú:ʕed
1p	waṣáfna	mnú:ṣef	nú:ṣef	waʕádna	mnú:ʕed	nú:ʕed
imp	wṣé:f, wṣə́fi, wṣə́fu			wʕé:d, wʕə́di, wʕə́du		

Apart from the vocalization of root initial *w* with *ə*, these verbs behave just like roots such as *ħamal*. Similarly, stems with initial *w* may have the vocalic pattern *e* in the perfective ~ *a* in the imperfective, and such verbs behave exactly like their counterparts with a non-glide in initial position (e.g. deletion the vowel /i/ in an unstressed open syllable).

(60)

	'fall'			'arrive'		
	perf.	impf. ind.	impf. sbj	perf.	impf. ind.	impf. sbj
3m	wəʔeʕ	byú:ʔaʕ	yú:ʔaʕ	wəṣel	byú:ṣal	yú:ṣal
3f	wəʔʕet	btú:ʔaʕ	tú:ʔaʕ	wəṣlet	btú:ṣal	tú:ṣal
3p	wəʔʕu	byú:ʔaʕu	yú:ʔaʕu	wəṣlu	byú:ṣalu	yú:ṣalu
2m	wʔéʕət	btú:ʔaʕ	tú:ʔaʕ	wṣélət	btú:ṣal	tú:ṣal
2f	wʔéʕti	btú:ʔaʕi	tú:ʔaʕi	wṣélti	btú:ṣali	tú:ṣali
2p	wʔéʕtu	btú:ʔaʕu	tú:ʔaʕu	wṣéltu	btú:ṣalu	tú:ṣalu
1s	wʔéʕət	bú:ʔaʕ	ʔú:ʔaʕ	wṣélət	bú:ṣal	ʔú:ṣal
1p	wʔéʕna	mnú:ʔaʕ	nú:ʔaʕ	wṣélna	mnú:ṣal	nú:ṣal
imp	wʔá:ʕ, wʔáʕi, wʔáʕu			wṣá:l, wṣáli, wṣálu		

One stem begins with the glide *y*, which selects this same vowel pattern. As the following paradigm shows, the glide *y* vocalizes to long *i:*.

(61)

	'dry up'		
	perf.	impf. ind.	impf. sbj
3m	yə́bes	byí:bas	yí:bas
3f	yə́bset	btí:bas	tí:bas
3p	yə́bsu	byí:basu	yí:basu
2m	ybə́sət	btí:bas	tí:bas
2f	ybə́sti	btí:basi	tí:basi
2p	ybə́stu	btí:basu	tí:basu
1s	ybə́sət	bí:bas	ʔí:bas
1p	ybə́sna	mní:bas	ní:bas
imp	ybá:s, ybási, ybásu		

This can be explained by a simple generalization of Glide Vocalization to include all glides.

2.4. CV:C Stems

Not all stems are of the surface shape CVCVC, and in this section we consider the phonology of stems with the shape CV:C, whose phonology differs considerably from that of CVCVC stems. We begin with stems which select the vocalism *a* in both the perfective and imperfective in (62).

(62)

	'sleep'			'appear'		
	perf.	impf. ind.	impf. sbj	perf.	impf. ind.	impf. sbj
3m	ná:m	biná:m	ynáːm	bá:n	bibá:n	ybá:n
3f	ná:met	bətná:m	tná:m	bá:net	bətbá:n	tbá:n
3p	ná:mu	biná:mu	ynáːmu	bá:nu	bibá:nu	ybá:nu
2m	nə́mət	bətná:m	tná:m	bə́nət	bətbá:n	tbá:n
2f	nə́mti	bətná:mi	tná:mi	bə́nti	bətbá:ni	tbá:ni
2p	nə́mtu	bətná:mu	tná:mu	bə́ntu	bətbá:nu	tbá:nu
1s	nə́mət	bná:m	ná:m	bə́nət	bbá:n	bá:n
1p	nə́mna	mənná:m	nná:m	bə́nna	mənbá:n	nbá:n
imp	ná:m, ná:mi, ná:mu			bá:n, bá:ni, bá:nu		

	'fear'			'contain'		
	perf.	impf. ind.	impf. sbj	perf.	impf. ind.	impf. sbj
3m	xá:f	bixá:f	yxá:f	sá:ʕ	bisá:ʕ	ysá:ʕ
3f	xá:fet	bətxá:f	txá:f	sá:ʕet	bətsá:ʕ	tsá:ʕ
3p	xá:fu	bixá:fu	yxá:fu	sá:ʕu	bisá:ʕu	ysá:ʕu
2m	xə́fət	bətxá:f	txá:f	sə́ʕət	bətsá:ʕ	tsá:ʕ
2f	xə́fti	bətxá:fi	txá:fi	sə́ʕti	bətsá:ʕi	tsá:ʕi
2p	xə́ftu	bətxá:fu	txá:fu	sə́ʕtu	bətsá:ʕu	tsá:ʕu
1s	xə́fət	bxá:f	xá:f	sə́ʕət	bsá:ʕ	sá:ʕ
1p	xə́fna	mənxá:f	nxá:f	sə́ʕna	mənsá:ʕ	nsá:ʕ
imp	xá:f, xá:fi, xá:fu			sá:ʕ, sá:ʕi, sá:ʕu		

We will first take on the perfective conjugation. The alternation that needs to be accounted for in this tense is between Ca:C and CəC. Stems of the shape Ca:C appear either when there is no suffix, or before the suffixes *-u* and *-et*, and stems of the shape CəC are found before suffixes of the shape CV and *ə*C. This distribution can be regularized by modifying our assumption about the underlying form of the suffixes for 2m and 1s which seem to be /ət/. It was previously noted that there are no clusters of three consonants in the language and that such clusters, when created, are broken up by insertion of the vowel schwa. There are also no clusters of the form CC at the end of a word (except identical consonant clusters). This fact raises the possibility that these suffixes are really /t/, and that the vowel is epenthetic. If that is the case, then the distribution of the two stem variants, Ca:C and CəC can be stated simply as: Ca:C becomes CəC before a consonant-initial suffix. This allows us to posit the following rule.

(63) *Pre-cluster shortening*
V: → ə / ___ CC

Furthermore, assuming that the 2m and 1s suffixes are really /t/ and that their vowel is epenthetic now allows us to make more sense of the stress pattern of the

language. Pursuing that assumption, examples of stress in the perfective and imperfective tenses of 'ask' are given, without the epenthetic vowel.

(64)	3m	sáʔal	b-yə́-sʔal
	3f	sáʔl-et	b-tə́-sʔal
	3p	sáʔal-u	b-yə́-sʔal-u
	2m	saʔál-t	b-tə́-sʔal
	2f	saʔál-ti	b-tə́-sʔal-i
	2p	saʔál-tu	b-tə́-sʔal-u
	1s	saʔál-t	b-ə́-sʔal
	1p	saʔál-na	m-nə́-sʔal

From this, we can see that stress falls on the final vowel if it is followed by two consonants, otherwise on the penult if that vowel is followed by two consonants, and on the antepenult if neither of the following vowels are followed by two consonants. In order to be consistent with the theory of stress assignment, and because additional data will be better accounted for if we do so, we restate the generalization not directly in terms of counting consonants, but rather in terms of an abstract property of syllables, namely we will distinguish between light and heavy syllables. In Syrian Arabic, heavy syllables are ones containing a long vowel, or a short vowel plus a consonant, except that at the end of a word, a single final consonant does not suffice to make a syllable heavy, but two consonants do. Stated in those terms, the generalization regarding stress is that the rightmost heavy syllable is stressed. In the following rule, σ indicates 'syllable' and σ̆ indicates 'light syllable': this rule allows up to two light syllables to be skipped over in placing stress.

(65) *Stress assignment*
$\sigma \rightarrow \acute{\sigma}$ / __ ((σ̆)σ̆) #

At this point, we can turn to the conjugation of CV:C verbs in the imperfective subjunctive. We see in (66) that while there is no alternation in the shape of the stem in the imperfective, there is variation in the shape of the prefix, compared to CVCVC verbs.

(66)		'fear'	'ask'
	3m	y-xá:f	yə́-sʔal
	3f	t-xá:f	tə́-sʔal
	3p	y-xá:fu	yə́-sʔalu
	2m	t-xá:f	tə́-sʔal
	2f	t-xá:fi	tə́-sʔali
	2p	t-xá:fu	tə́-sʔalu
	1s	xá:f	ʔə́-sʔal
	1p	n-xá:f	nə́-sʔal

The explanatory basis for most of this alternation is already available. Following the rule for stress assignment which we have proposed, we would expect to find forms, after stress is assigned, such as /yə-xá:f/, /yə-xá:f-u/. Stress is assigned to the stem vowel because it is long, in contrast to that of *yə́sʔal*. These forms contain unstressed schwa in a closed syllable, which we have seen is subject to deletion. Given application of the schwa deletion rule, all forms of the imperfective subjunctive are accounted for, save for the 1s form.

As for the 1s imperfective form, recall that that prefix was assumed to be /ə/. Beginning with the underlying form /ə-xa:f/, stress assignment gives *əxá:f*, then schwa deletion gives the phonetic form *xá:f*. This then completes the analysis of the imperfective subjunctive, so we turn to the indicative, to see the effect of adding the prefix *b*-. Representative examples of indicative and subjunctive CV:C stems and indicative CVCVC stems are contrasted in (67).

(67)		fear (subjunct)	fear (indic)	ask (indic)
	3m	y-xá:f	b-i-xá:f	b-yə́-sʔal
	3f	t-xá:f	bə-t-xá:f	b-tə́-sʔal
	3p	y-xá:fu	b-i-xá:fu	b-yə́-sʔalu
	2m	t-xá:f	bə-t-xá:f	b-tə́-sʔal
	2f	t-xá:fi	bə-t-xá:fi	b-tə́-sʔali
	2p	t-xá:fu	bə-t-xá:fu	b-tə́-sʔalu
	1s	xá:f	b-xá:f	b-ə́-sʔal
	1p	n-xá:f	mə-n-xá:f	m-nə́-sʔal

Simply adding the indicative prefix to the subjunctive form *txa:f* would yield *btxá:f*, with a cluster of three consonants: the surface form derives by applying epenthesis. On the other hand, in the 1s form no such consonant cluster arises, and therefore no vowel is inserted. It should also be noted, given the surface form *mənxá:f* from /b-nə-xá:f/, that the rule of *b*-nasalization must apply before epenthesis, since the latter rule separates *b* and the triggering nasal consonant.

Another set of forms to be concerned with in the indicative paradigm of CV:C verbs is *bixá:f, bixá:fu*. From the underlying forms /b-yə-xá:f/, /b-yə-xá:f-u/ we would expect to derive *bəyxá:f(u)*, considering only stress assignment, *ə*-deletion, and epenthesis. In addition, however, we have the rule of glide vocalization which should apply to these forms giving *bi:xá:f(u)*. This is almost the corect output, except for vowel length. At this point it is not clear whether the shortening of the first vowel is due to it standing before another long vowel, or is due to being unstressed. We will assume the latter explanation, and will seek further evidence for that choice below.

(68) *Unstressed shortening*

V
[-stress] → [-long]

Finally, it should be noted that in the imperative, the stem vowel is long in the singular masculine where no affix added, and in the feminine and plural forms where a -V suffix is added. This contrasts with stems such as *któ:b* ~ *któbi*: the difference is that in *któ:b* vowel length is assigned to satisfy the word minimality requirement but in *xá:f* ~ *xá:fi* the stem has an underlying long vowel. This then complete the analysis of CV:C stems having the vocalic pattern *a* ~ *a*.

In (69) are given examples of CV:C verbs with the vocalic pattern *a* for the perfective, *u* for the imperfective.

(69)

	'drive'			'say'		
	perf.	impf. ind.	impf. sbj	perf.	impf. ind.	impf. sbj
3m	sá:ʔ	bisú:ʔ	ysú:ʔ	ʔá:l	biʔú:l	yʔú:l
3f	sá:ʔet	bətsú:ʔ	tsú:ʔ	ʔá:let	bətʔú:l	tʔú:l
3p	sá:ʔu	bisú:ʔu	ysú:ʔu	ʔá:lu	biʔú:lu	yʔú:lu
2m	sə́ʔət	bətsú:ʔ	tsú:ʔ	ʔə́lət	bətʔú:l	tʔú:l
2f	sə́ʔti	bətsú:ʔi	tsú:ʔi	ʔə́lti	bətʔú:li	tʔú:li
2p	sə́ʔtu	bətsú:ʔu	tsú:ʔu	ʔə́ltu	bətʔú:lu	tʔú:lu
1s	sə́ʔət	bsú:ʔ	sú:ʔ	ʔə́lət	bʔú:l	ʔú:l
1p	sə́ʔna	mənsú:ʔ	nsú:ʔ	ʔə́lna	mənʔú:l	nʔú:l
imp	sú:ʔ, sú:ʔi, sú:ʔu			ʔú:l, ʔú:li, ʔú:lu		

	'visit'			'blame'		
	perf.	impf. ind.	impf. sbj	perf.	impf. ind.	impf. sbj
3m	zá:r	bizú:r	yzú:r	lá:m	bilú:m	ylú:m
3f	zá:ret	bətzú:r	tzú:r	lá:met	bətlú:m	tlú:m
3p	zá:ru	bizú:ru	yzú:ru	lá:mu	bilú:mu	ylú:mu
2m	zə́:rət	bətzú:r	tzú:r	lə́:mət	bətlú:m	tlú:m
2f	zə́rti	bətzú:ri	tzú:ri	lə́mti	bətlú:mi	tlú:mi
2p	zə́rtu	bətzú:ru	tzú:ru	lə́mtu	bətlú:mu	tlú:mu
1s	zə́rət	bzú:r	zú:r	lə́mət	blú:m	lú:m
1p	zə́rna	mənzú:r	nzú:r	lə́mna	mənlú:m	nlú:m
imp	zú:r, zú:ri, zú:ru			lú:m, lú:mi, lú:mu		

The importance of this set of verbs is the realization of the imperfective vowel. Previous verbs have presented [a], [o] and [e], and never *[u], *[i] as the vowel of the imperfective. With CV:C verbs, we find the long vowels [a:], [u:] and (below) [i:], never *[o], *[e]. This complementarity suggests that the tense-related vocalism reduces to a single, simpler system with just three vowels — /a,u,i/ — and derive mid vowel by a rule which is sensitive to vowel length.

(70) *Vowel Lowering*

$$\begin{matrix} \text{V} \\ \text{[-long]} \end{matrix} \rightarrow \text{[-hi]}$$

This predicts that there should be no short vowels [i], [u] in the language, which is wrong: cf. *bixá:f* 'he fears'. This high vowel derives from a long vowel by unstressed vowel shortening, so this is not a serious counteraxample. More problematic is that the suffixes *-u, -tu, -i, -ti* do not undergo lowering. There are three explanations for this. First, the suffixes might have underlying long vowels (shortened because they are unstressed), so escape lowering. The difficulty with this account is that it becomes hard to explain why these vowels are not stressed, when stress otherwise seeks the last heavy syllable. The second alternative is that lowering is morphologically restricted so that it does not affect suffixes. A third possibility is that reduction does not affect word-final vowels. Lacking evidence to choose between alternatives, we do not make a specific decision at this point.

The data in (71) provides examples of CV:C stems selecting the vocalic pattern *a* ~ *i*, to complement the preceding data on the pattern *a* ~ *u*.

(71)

	'wake up'			'be absent'		
	perf.	impf. ind.	impf. sbj	perf.	impf. ind.	impf. sbj
3m	fá:ʔ	bifí:ʔ	yfí:ʔ	γá:b	biγí:b	yγí:b
3f	fá:ʔet	bətfí:ʔ	tfí:ʔ	γá:bet	bətγí:b	tγí:b
3p	fá:ʔu	bifí:ʔu	yfí:ʔu	γá:bu	biγí:bu	yγí:bu
2m	fə́ʔət	bətfí:ʔ	tfí:ʔ	γə́bət	bətγí:b	tγí:b
2f	fə́ʔti	bətfí:ʔi	tfí:ʔi	γə́bti	bətγí:bi	tγí:bi
2p	fə́ʔtu	bətfí:ʔu	tfí:ʔu	γə́btu	bətγí:bu	tγí:bu
1s	fə́ʔət	bfí:ʔ	fí:ʔ	γə́bət	bγí:b	γí:b
1p	fə́ʔna	mənfí:ʔ	nfí:ʔ	γə́bna	mənγí:b	nγí:b
imp	fí:ʔ, fí:ʔi, fí:ʔu			γí:b, γí:bi, γí:bu		

	'remove'			'live'		
	perf.	impf. ind.	impf. sbj	perf.	impf. ind.	impf. sbj
3m	ʔá:m	biʔí:m	yʔí:m	ʕá:š	biʕí:š	yʕí:š
3f	ʔá:met	bətʔí:m	tʔí:m	ʕá:šet	bətʕí:š	tʕí:š
3p	ʔá:mu	biʔí:mu	yʔí:mu	ʕá:šu	biʕí:šu	yʕí:šu
2m	ʔə́mət	bətʔí:m	tʔí:m	ʕə́šət	bətʕí:š	tʕí:š
2f	ʔə́mti	bətʔí:mi	tʔí:mi	ʕə́šti	bətʕí:ši	tʕí:ši
2p	ʔə́mtu	bətʔí:mu	tʔí:mu	ʕə́štu	bətʕí:šu	tʕí:šu
1s	ʔə́mət	bʔí:m	ʔí:m	ʕə́šət	bʕí:š	ʕí:š
1p	ʔə́mna	mənʔí:m	nʔí:m	ʕə́šna	mənʕí:š	nʕí:š
imp	ʔí:m, ʔí:mi, ʔí:mu			ʕí:š, ʕí:ši, ʕí:šu		

This then completes the analysis of CV:C verb stems.

2.5. CVCCVC stems

Another class of stems has the shape CVCCVC. The examples in (72) have the vowel *a* in the perfective and *i* in the imperfective.

(72)

	'close'			'try'		
		perf.	impf. ind.	perf.	impf. ind.	impf. sbj
3m	sákkar	bisákker	tsákker	žárrab	bižárreb	tžárreb
3f	sákkaret	bətsákker	tsákker	žárrabet	bətžárreb	tžárreb
3p	sákkaru	bisákkru	ysákkru	žárrabu	bižárrbu	yžárrbu
2m	sakkárət	bətsákker	tsákker	žarrábət	bətžárreb	tžárreb
2f	sakkárti	bətsákkri	tsákkri	žarrábti	bətžárrbi	tžárrbi
2p	sakkártu	bətsákkru	tsákkru	žarrábtu	bətžárrbu	tžárrbu
1s	sakkárət	bsákker	sákker	žarrábət	bžárreb	žárreb
1p	sakkárna	mənsákker	nsákker	žarrábna	mənžárreb	nžárreb
imp	sákker, sákkri, sákkru		žárreb, žárrbi, žárrbu			

This paradigm reinforces aspects of our analysis of vowel deletion. We saw two patterns of vowel deletion, one via an apocope rule deleting unstressed non-low vowels in an open syllable, and one via a syncope rule deleting unstressed *a* in an open syllable, when the vowel is preceded by VC. Underlying /sakkaret/ cannot undergo syncope of /a/ because the vowel is preceded by a consonant cluster; but, /yə-sakkir-u/ undergoes apocope of *i* despite the preceding consonant cluster.

2.6. CVCV Stems

Our next class of verb stems are those of the shape CVCV. Consideration of these stems will lead us to posit a new rule. We will start with verbs having *a* in all tenses: examples are given in (73).

(73)

	'read'			'begin'		
	perf.	impf. ind.	impf. sbj	perf.	impf. ind.	impf. sbj
3m	ʔára	byə́ʔra	yə́ʔra	báda	byə́bda	yə́bda
3f	ʔáret	btə́ʔra	tə́ʔra	bádet	btə́bda	tə́bda
3p	ʔáru	byə́ʔru	yə́ʔru	bádu	byə́bdu	yə́bdu
2m	ʔaré:t	btə́ʔra	tə́ʔra	badé:t	btə́bda	tə́bda
2f	ʔaré:ti	btə́ʔri	tə́ʔri	badé:ti	btə́bdi	tə́bdi
2p	ʔaré:tu	btə́ʔru	tə́ʔru	badé:tu	btə́bdu	tə́bdu
1s	ʔaré:t	bə́ʔra	ʔə́ʔra	badé:t	bə́bda	ʔə́bda
1p	ʔaré:na	mnə́ʔra	nə́ʔra	badé:na	mnə́bda	nə́bda
imp	ʔra:, ʔri:, ʔru:				bda:, bdi:, bdu:	

	'disobey'			'grow'		
	perf.	impf. ind.	impf. sbj	perf.	impf. ind.	impf. sbj
3m	ʕáṣa	byə́ʕṣa	yə́ʕṣa	náma	byə́nma	yə́nma
3f	ʕáṣet	btə́ʕṣa	tə́ʕṣa	námet	btə́nma	tə́nma
3p	ʕáṣu	byə́ʕṣu	yə́ʕṣu	námu	byə́nmu	yə́nmu
2m	ʕaṣé:t	btə́ʕṣa	tə́ʕṣa	namé:t	btə́nma	tə́nma
2f	ʕaṣé:ti	btə́ʕṣi	tə́ʕṣi	namé:ti	btə́nmi	tə́nmi
2p	ʕaṣé:tu	btə́ʕṣu	tə́ʕṣu	namé:tu	btə́nmu	tə́nmu
1s	ʕaṣé:t	bə́ʕṣa	ʔə́ʕṣa	namé:t	bə́nma	ʔə́nma
1p	ʕaṣé:na	mnə́ʕṣa	nə́ʕṣa	namé:na	mnə́nma	nə́nma
imp	ʕṣa:, ʕṣi:, ʕṣu:			nma:, nmi:, nmu:		

In the perfective tense, we encounter a number of alternations at the juncture of the stem final vowel *a* and a following suffix. On the one hand, if the following suffix begins with a vowel, the stem vowel *a* is deleted; thus underlying *ʔara-et* and *ʔara-u* surface as *ʔar-et* and *ʔar-u*, due to the following rule. We note that there are no clusters of vowels in any of our data for this language.

(74) *Vowel cluster simplification*
V → ∅ / __ V

On the other hand, when the stem is followed by a consonant-initial suffix, the final stem vowel becomes [e:]. We will tenatively formalize this rule as in (75), but will re-analyze this process when additional data is available.

(75) a → e: / ___ + C

Note that the 2m and 1s suffixes, which appear as *-ət* when added to a consonant final stem, pattern with other consonant initial suffixes in triggering this rule. We have seen other evidence supporting the claim that the schwa in these suffixes is epenthetic, since these suffixes pattern with other consonant initial suffixes with respect to stress assignment and the shortening of stem vowels in CV:C verbs.

The derivation of imperfective forms does not pose any particular challenge, given that we have motivated a rule deleting a stem vowel before a suffix vowel. Surface [byə́ʔra] derives from /b-yə-ʔra/ by stress assignment, and /b-yə-ʔra-u/ becomes [byə́ʔru] by vowel cluster reduction and stress. The imperative forms *ʔrá:, ʔrí:, ʔrú:* merit a brief comment. These derive from /ʔra/, /ʔra-i/, /ʔra-u/. Vowel cluster reduction and stress apply to give *ʔrá, ʔrí, ʔrú*, and lengthening the of vowel in subminimal words then accounts for the long vowel in these forms.

The next set of stems that we will consider are those with *a* in the perfective and *i* in the imperfective, examples being given in (76).

(76)

	'build'			'invoke'		
	perf.	impf. ind.	impf. sbj	perf.	impf. ind.	impf. sbj
3m	bána	byə́bni	yə́bni	dáʕa	byə́dʕi	yə́dʕi
3f	bánet	btə́bni	tə́bni	dáʕet	btə́dʕi	tə́dʕi
3p	bánu	byə́bnu	yə́bnu	dáʕu	byə́dʕu	yə́dʕu
2m	bané:t	btə́bni	tə́bni	daʕé:t	btə́dʕi	tə́dʕi
2f	bané:ti	btə́bni	tə́bni	daʕé:ti	btə́dʕi	tə́dʕi
2p	bané:tu	btə́bnu	tə́bnu	daʕé:tu	btə́dʕu	tə́dʕu
1s	bané:t	bə́bni	ʔə́bni	daʕé:t	bə́dʕi	ʔə́dʕi
1p	bané:na	mnə́bni	nə́bni	daʕé:na	mnə́dʕi	nə́dʕi
imp	bní:, bní:, bnú:			dʕí:, dʕí:, dʕú:		

	'extinguish'			'speak'		
	perf.	impf. ind.	impf. sbj	perf.	impf. ind.	impf. sbj
3m	ṭáfa	byə́ṭfi	yə́ṭfi	ħáka	byə́ħki	yə́ħki
3f	ṭáfet	btə́ṭfi	tə́ṭfi	ħáket	btə́ħki	tə́ħki
3p	ṭáfu	byə́ṭfu	yə́ṭfu	ħáku	byə́ħku	yə́ħku
2m	ṭafé:t	btə́ṭfi	tə́ṭfi	ħaké:t	btə́ħki	tə́ħki
2f	ṭafé:ti	btə́ṭfi	tə́ṭfi	ħaké:ti	btə́ħki	tə́ħki
2p	ṭafé:tu	btə́ṭfu	tə́ṭfu	ħaké:tu	btə́ħku	tə́ħku
1s	ṭafé:t	bə́ṭfi	ʔə́ṭfi	ħaké:t	bə́ħki	ʔə́ħki
1p	ṭafé:na	mnə́ṭfi	nə́ṭfi	ħaké:na	mnə́ħki	nə́ħki
imp	ṭfí:, ṭfí:, ṭfú:			ħkí:, ħkí:, ħkú:		

The perfectives are parallel to the perfectives of *ʔara* etc. so they require no comment. The imperfectives derive simply, given the rule of vowel cluster reduction and the underlying vowel which they select in the imperfective. Underlying /tə-bni/ surfaces as [tə́bni] 'she built', and /tə-bni-i/ surfaces as homophonous [tə́bni] 'you f. built' (cf. /tə-ʔra/ → [tə́ʔra] 'she read', /tə-ʔra-i/ → [tə́ʔri] 'you f. read').

The third class of vowel final verbs are those which select the vowel *i* in the perfective and *a* in the imperfective.

(77)

	'stay'			'get stuck'		
	perf.	impf. ind.	impf. sbj	perf.	impf. ind.	impf. sbj
3m	bə́ʔi	byə́bʔa	yə́bʔa	šə́fi	byə́šfa	yə́šfa
3f	bə́ʔyet	btə́bʔa	tə́bʔa	šə́fyet	btə́šfa	tə́šfa
3p	bə́ʔyu	byə́bʔu	yə́bʔu	šə́fyu	byə́šfu	yə́šfu
2m	bʔí:t	btə́bʔa	tə́bʔa	šfí:t	btə́šfa	tə́šfa
2f	bʔí:ti	btə́bʔi	tə́bʔi	šfí:ti	btə́šfi	tə́šfi
2p	bʔí:tu	btə́bʔu	tə́bʔu	šfí:tu	btə́šfu	tə́šfu
1s	bʔí:t	bə́bʔa	ʔə́bʔa	šfí:t	bə́šfa	ʔə́šfa
1p	bʔí:na	mnə́bʔa	nə́bʔa	šfí:na	mnə́šfa	nə́šfa
imp	bʔá:, bʔí:, bʔú:			šfá:, šfí:, šfú:		

The inflection of the imperfective of these verbs is exactly identical to that of *a* ~ *a* verbs like *ʔára*. The perfective on the other hand requires some analysis. We can see that before a vowel-initial suffix in the perfective, the final vowel becomes the glide *y*. Thus, /bəʔi-et/ becomes [bə́ʔyet] and /bəʔi-u/ becomes [bəʔyu]. Obvious, a rule of glide formation is at work in these data. However, we must ask why no glide formation was found in apparently parallel forms such as /tə-bni-u/ → [təbnu] 'you pl. built'. The answer is that the forms are not entirely parallel, and the crucial difference is the number of consonants appearing before the stem final vowel. In the case of /bəʔi-et/, Glide Formation can apply without creating an illicit sequence of three consonants, so [bə́ʔyet] results. In /tə-bni-u/ on the other hand, were Glide Formation to apply, illicit *[tə́bnyu] with a CCC sequence would result. Therefore, we must constrain Glide Formation so that its application does not result in three consonants.

(78) *Glide Formation*

$$\begin{matrix} \text{V} \\ [+\text{hi}] \end{matrix} \rightarrow [-\text{syllabic}] \ / \ \text{V C} \_\_\_ \text{V}$$

A final set of CVCV verbs will be considered here, namely those whose initial consonant is a glide. We have previously seen that initial glides are subject to a vocalization process in imperfective forms, and CVCV verbs are subject to such a process. The verb in (79) illustrates the conjugation of a verbs with the vowel pattern *i* ~ *a*.

(79) 'be low'

	perf.	impf. ind.	impf. sbj
3m	wə́ṭi	byú:ṭa	yú:ṭa
3f	wə́ṭyet	btú:ṭa	tú:ṭa
3p	wə́ṭyu	byú:ṭu	yú:ṭu
2m	wṭí:t	btú:ṭa	tú:ṭa
2f	wṭí:ti	btú:ṭi	tú:ṭi
2p	wṭí:tu	btú:ṭa	tú:ṭa
1s	wṭí:t	bú:ṭa	ʔú:ṭa
1p	wṭí:na	mnú:ṭa	nú:ṭa
imp	wṭá:, wṭí:, wṭú:		

Glide vocalization applies as expected in the imperfective. Underlying /b-yə-wṭa-i/ undergoes stress assignment and vowel cluster reduction to give intermediate *byə́wṭi*, which then undergoes glide vocalization to give surface [byu:tị]

The examples in (80) involve a verb with *a* in the perfective and *i* in the imperfective.

(80)

	perf.	impf. ind.	impf. sbj
3m	wáfa	byú:fi	yú:fi
3f	wáfet	btú:fi	tú:fi
3p	wáfu	byú:fu	yú:fu
2m	wafé:t	btú:fi	tú:fi
2f	wafé:ti	btú:fi	tú:fi
2p	wafé:tu	btú:fu	tú:fu
1s	wafé:t	bú:fi	ʔú:fi
1p	wafé:na	mnú:fi	nú:fi
imp	wfí:, wfí:, wfú:		

The perfective forms are just like other CVCV verbs having the vowel *a*. The imperfective forms can also be derived from the rules available. The form [yú:fi] derives from underlying /yə-wfi/; stress assignment gives the intermediate form [yə́wfi], and the derivation of this form is completed by applying glide vocalization. The form [yú:fu] derives from /yə-wfi-u/ analogously. The rules applicable here are stress assignment, glide vocalization, and vowel cluster reduction. Note that glide formation might, in principle, apply to /yə-wfi-u/, but does not. Evidently, the verb has a consonant cluster at the stage where Glide Formation might apply, and that consonant cluster prevents Glide Formation from applying. Later, Glide vocalization eliminates the glide from the surface, but this process is ordered after the decision has been made to not apply Glide Formation.

2.6.1. CVCC Stems

The final class of verbs which will be considered are those of the shape CVCC, where the final two consonants are identical. Examples with a verb selecting *a* in the two tenses are given in (81).

(81)

	'remain'			'remain'		
	perf.	impf. ind.	impf. sbj	perf.	impf. ind.	impf. sbj
3m	támm	bitámm	ytámm	ḍáll	biḍáll	yḍáll
3f	támmet	bəttámm	ttámm	ḍállet	bətḍáll	tḍáll
3p	támmu	bitámmu	ytámmu	ḍállu	biḍállu	yḍállu
2m	tammé:t	bəttámm	ttámm	ḍallé:t	bətḍáll	tḍáll
2f	tammé:ti	bəttámmi	ttámmi	ḍallé:ti	bətḍálli	tḍálli
2p	tammé:tu	bəttámmu	ttámmu	ḍallé:tu	bətḍállu	tḍállu
1s	tammé:t	btámm	támm	ḍallé:t	bḍáll	ḍáll
1p	tammé:na	məntámm	ntámm	ḍallé:na	mənḍáll	nḍáll
imp	támm, támmi, támmu			ḍáll, ḍálli, ḍállu		

The aspect of these verbs which is most in need of comment is the fact that in the perfective tense, epenthetic *e:* is found before consonant initial suffixes. We have

previously encountered this *e:* in the conjugation of CVCV verbs, where we assumed that it represented a change of the underlying vowel to *e:*. However, another possibility is that with CVCV verbs, *e:* is inserted, giving intermediate *ʔarae:t*, and then vowel cluster reduction applies to give the surface form. The appearance of *e:* in the same context with CVCC verbs give credence to that analysis. What remains to be clarified is the context where *e:* is inserted: we find *e*: inserted after stems of the form CVCC and CVCV, as expressed in the following rule.

(82) *Stem augmentation*

$$\varnothing \rightarrow \text{e:} / \text{CVC} \begin{Bmatrix} \text{C} \\ \text{V} \end{Bmatrix} \_\_\_ + \text{C}$$

The rules which have been motivated here, and the important orderings, are summarized below. A number of rules can be assumed to apply relatively early, and their specific ordering is not particularly important.

Syncope	$\text{a} \rightarrow \varnothing$ / VC __ Ce
Nasalization	b → [+nasal] / __ [+nasal]
Lengthening	$\text{V} \rightarrow \text{VV} / \#\text{C}_0$ __ C#
Stem augmentation	$\varnothing \rightarrow \text{e:} / \text{CVC} \begin{Bmatrix} \text{C} \\ \text{V} \end{Bmatrix} \_\_\_ + \text{C}$
Stress assignment	σ → σ́ / __ ((σ̆)σ̆) #
Pre-cluster shortening	V: → ə / ___ CC

For other rules, the order of application becomes more important.

Nonlow vowel deletion	$\begin{bmatrix} \text{V} \\ \text{-stress} \\ \text{-low} \end{bmatrix} \rightarrow \varnothing$ / _ CV
Glottal Prothesis	$\varnothing \rightarrow$ ʔ / # ___ V
Epenthesis	$\varnothing \rightarrow$ ə / C __ CC

Glide Vocalization ə w C → u: C

Vowel lowering $\begin{matrix} V \\ [\text{-long}] \end{matrix} \rightarrow [\text{-hi}]$

Mid vowel reduction e,o → ə / __ C_0 V

Unstressed shortening $\begin{matrix} V \\ [\text{-stress}] \end{matrix} \rightarrow [\text{-long}]$

Glide Formation $\begin{matrix} V \\ [\text{+hi}] \end{matrix} \rightarrow [\text{-syllabic}]$ / V C ___ V

Vowel cluster simplification V → ∅ / __ V

10

Abstractness and Psychological Reality

This chapter explores the extent to which underlying and surface forms can be different — what constraints if any are tenable within the formal theory, what the issues are in limiting abstractness, and how to address these questions empirically. The central question raised in this chapter is "what counts as evidence for a phonological analysis?".

A fundamental question of phonology has been "how abstract is phonology", specifically, how different can the underlying and phonetic forms of a word be? The heart of this question is whether grammars of languages require entities that are not directly observed. Intimately related to this is the question whether a linguistic model that requires elements that cannot be directly observed reflects what the human mind is actually capable of. The very concept of a mental representation of speech, such as a phonological surface form like [sɔks] "socks" which is not itself an observable physical event, requires abstracting away from many specifics of speech. Without generalizing beyond the directly observable, it would be impossible to make even the most mundane observations about any language. The question is therefore not whether phonology is abstract at all, but rather what degree of abstractness is required.

If underlying representations are fully concrete — if they are the same as surface representations — the underlying forms of English [k^{h}ɔrts] "courts" and [k^{h}owdz] "codes" would be /k^{h}ɔrt-s/ and /k^{h}owd-z/. Such an extremely surface-oriented view of phonology would pay no attention to the fact that these words have in common the plural morpheme, whose pronunciation varies according to the environment. By hypothesizing that the underlying form of [k^{h}ɔrts] is /k^{h}ɔrt-z/, we can say that the plural pronounced *s* in [k^{h}ɔrts] and the plural pronounced *z* in [k^{h}owdz] are one and the same thing, thus we standardly accept an element of abstractness in all phonological analysis, because of the benefits which this abstractness yields in terms of giving a unified explanation to the various ways in which the plural morpheme is pronounced.

1. Why Limit Abstractness?

First we must understand what motivates concern over abstractness.

1.1. Limiting possible analyses

One reason to limit the divergence between underlying and surface forms is to constrain the theory of phonology, to prevent it from making wrong claims about how languages work. With no constraint on abstractness, every conceivable derivation from underlying to surface form would in principle be allowed by the theory. Just as the theory of phonology seeks to constrain the concept of "possible rule", so that an imaginable rule such as {s,p,q,r} → {m,l,t,v} / __ {s,k,ə,m} (unattested in any human language) can be ruled out on formal grounds, so too might we wish to rule out a derivation from underlying /qöɬɨɟʌ/ to surface [gəráž] as too abstract. Since a goal of linguistic theory has been to restrict the class of theoretically possible languages to just the type that is actually observed, limiting abstractness in a well-defined way limits the number of possible languages.

Another reason for concern over abstractness is that it makes a particular claim about human cognition, that the mentally stored units of language can include things that the speaker has not actually heard, but arrives at by inference based on a line of indirect evidence. Since first language acquisition does not procede by conscious reasoning, it cannot be taken for granted that everyday reasoning skills are automatically available to children.

Mental reality and language acquisition. This second consideration, whether abstractness (of some particular degree) is part of human cognitive capacity, is the most important question arising in this debate: this is a fundamental consideration, for a theory that seeks a model of language in the mind. Because the details of specific languages are not built into children at birth but must be induced from the ambient linguistic data aided by whatever language faculty is universally available to all humans (i.e. the theory of grammar), a basic concern regarding the psychological reality of grammatical constructs — for phonology, rules and underlying forms — is whether they can be learned from the primary language data.

The role of a universal grammatical component is to make the job of language acquisition easier, by uncompromisingly removing certain kinds of imaginable descriptions from consideration. The theory of distinctive features is one way of making the job of acquiring a language easier, since it limits the possible ways of analysing a set of data. Universal constraints on abstractness might similarly help a child trying to arrive at underlying representation for a language, and there have been a number of proposals as to the relationship between the underlying and surface forms. Attractive as it might seem to propose formal constraints on the theory of grammar to prohibit English from having /qöɬɨɟʌ/ be the underlying form of [gəráž] "garage", we will not actually assume that this is a matter for the formal theory of grammar; rather, it is a consequence of how a phonology is learned, thus the question of abstractness is outside the domain of grammatical theory.

Faced with a word pronounced [dɔg], a child learning English has no reason to assume that its underlying form is anything other than /dɔg/. But faced with the word "atom" [ǽɒəm] and the related word "atomic" [ət^{h}ɔ́mɪk], the child needs to arrive at an underlying representation for the root on which these two words are based, such that rules of English phonology can apply to derive the phonetic variants [ǽɒəm] and [ət^{h}ɔ́m-ɪk]: an appropriate representation would be [ætɔm]. It is in the face of such a specific motivation for an abstract underlying form that we would assume the underlying form isn't simply the surface form. The solution to the so-called problem of abstractness which will be adopted here is, simply, that abstractness per se is not a problem: what really requires investigation is the kind of evidence that properly motivates a phonological analysis.

Abstractness and phonemic representations. One particular degree of abstractness is widely accepted as self-evident, needing no further justification, namely that underlying representations do not contain allophonic variants of phonemes. It is generally assumed that English [stɔp], [t^{h}ɔp] are underlyingly /stɔp/, /tɔp/, without aspiration, because there is (by assumption) no underlying aspiration in English. Similarly, we know that the underlying form of [hɪɒɪŋ] "hitting" is /hɪtɪŋ/, not only because the flap is an allophone in English, but also because of the related word [hɪt] "hit" where the [t] is directly pronounced. Thus, it is commonly assumed that underlying forms are *at least* as abstract as phonemic representations, with all allophonically predictable features eliminated.

This assumption can lead to problems. What is the medial consonant in the underlying form of a word like [waɒr̩] "water"? Assuming that the flap is not a phoneme in English (there are no minimal or near-minimal pairs contrasting [t] or [d] vs. [ɒ]), this forces us to say that it must be something other than [ɒ]. The word is spelled with *t*, but spelling is not relevant to underlying representations. Children acquire words without knowing how to spell, and most languages of the world are unwritten yet underlying representations must be acquired for all human languages. Spelling is also unreliable, and could lead us to the unjustified conclusion that the underlying vowels of [tuw] "too", "to", "two", [θruw] "through", [duw] "due" and [druw] "drew" are all different.

Since [waɒr̩] is not composed of a root plus suffix, we cannot look at related forms to reveal the underlying consonant (as we can in "wad-er" versus "wait-er", both [weyɒr̩]). Any number of hypotheses could be set forth — /waɒr̩/, /watr̩/, /wadr̩/, /waðr̩/, /waβr̩/, /waγr̩/ and so on. Hypotheses like /waβr̩/ and /waγr̩/ can be rejected on the grounds that they are pointlessly abstract, containing segments which do not occur phonetically in English, and there is no reason to believe that they exist underlyingly. Nothing is gained by positing such underlying representations, thus nothing justifies these hypotheses. Two facts weight decisively against hypothetical /waβr̩/, /waγr̩/ and their ilk. First, there is no evidence for a rule in English effecting the change /γ/ → [ɒ] or /β/ → [ɒ] and addition of such a rule, required to convert the underlying form into the surface form, rules against

such an analysis since there exist analyses which at least do not force the inclusion of otherwise unmotivated rules. Second, a specific choice between /waβr̩/ and /waɣr̩/, or /waʕr̩/ and innumerable other possibilities which also lack an underlying flap, is totally arbitrary and leaves the language analyst — student and child alike — with the unresolvable puzzle "why *this* underlying form and not some other", which can only be resolved by fiat.

The hypothesis of underlying /waðr̩/ is less abstract in a qualitatively different way since it is composed only of observed segments of English; it is, however, factually wrong, because it would be impossible to craft rules for English to turn /ð/ into a flap in this context (consider "father", "bother", "weather" which indicate that there cannot be a rule changing /ð/ into a flap in some context). Only three hypotheses remain viable: /waɒr̩/, /watr̩/, and /wadr̩/. None of these hypotheses posits surface non-existent segments, and given the rules of English — Flapping, specifically — any of these underlying representations would result in the correct surface form.

There is no standard answer to the question of the underlying form of "water", but certain arguments can be marshalled to support different positions. We initially rejected the theory that the underlying form might be /waɒr̩/ because it posits what we assumed to be a non-existent underlying segment in the language, but we should reconsider that decision, to at least explicit our argument for rejecting an underlying flap. Hypothesizing /waɒr̩/ necessitates another phoneme in the inventory of English underlying segments, violating an analytic economy principle which says that you should select a parsimonious underlying inventory for a language. This reflects the basic principle of scientific reasoning that simpler, more economical solutions are better than complicated solutions that posit unnecessary machinery. But no concrete linguistic arguments indicate that elimination of phonemes is an actual goal of phonological acquisition. Economy of the underlying inventory cannot be judged in a theoretical vacuum, and in one contemporary theory, Optimality Theory, it is impossible to state generalizations about underlying representations, so it is impossible to say that English has no underlying flap.

A somewhat stronger argument against allowing an underlying flap is that the surface distribution of [ɒ] is limited. It only appears between vocoids (vowels and glides), and only if the following vowel is unstressed, which is precisely the context where /t,d/ actively are changed into the flap [ɒ] ("hit" [hɪt] ~ "hitting" [hɪɒɪŋ]; "hide" [hayd] ~ "hiding" [hayɒɪŋ]). We can explain the lack of words in English like *[hiɒ], *[ɒuwl], *[æfɒr̩] and *[əɒǽk], if we assume that the flap [ɒ] is not in the inventory of underlying segments of English, and only derives from /t/ or /d/ by this specific rule. This argument recognizes the importance of capturing major generalizations about language, which is the central concern of linguistics: it says that it would be too much of a coincidence if, in assuming underlying /ɒ/ in "water", we failed to note that underlying flap only appears in a very few contexts.

This argument is founded on the presumption that distribution of segments in underlying forms cannot be restricted: otherwise we would simply state a re-

striction on where underlying flaps appear and let the underlying form of [waɒɾ̩] be fully concrete. Some theories do not have conditions on underlying forms (Optimality Theory), others do. Something like conditions on underlying forms seem inevitable, since for example there cannot be any words in English of the form sC_iVC_i, hence **slil, *sneen, *spup, *skuck*; yet, it is uncertain what status such conditions have in the theory of grammar.

Still, even if we decide that the underlying form doesn't have a flap, that leaves open the choice between /t/ and /d/, which is purely arbitrary. The choice might be made by appealing to markedness (Chapter 8), insofar as [t] is a less marked i.e. crosslinguistically common segment than [d]. Whether this reasoning is correct remains to be determined empirically.

1.2. A principled limit on abstractness?

In connection with our first neutralization rule, final devoicing in Russian (chapter 4), we explained the alternation [porok] "threshold (nom. sg.)" ~ [poroga] "threshold (gen. sg.)" by saying that underlyingly the stem "threshold" ends with /g/. The abstract representation /porog/ for [porok] "threshold (nom. sg.)" is justified by the fact that the fact that [porok] and [poroga] have the same root morpheme, and /porog/ is one of the two actually occurring pronunciations of the morpheme. In hypothesizing underlying forms of morphemes, we have repeatedly emphasized the utility of considering any and all of the surface realizations of a given morpheme as candidates for being the underlying form. We might even advance a formal principle regarding abstractness:[1]

(1) The underlying form of a morpheme must actually be pronounced as such in some surface form containing the morpheme

When you look at a broad range of phonological analyses, it very often turns out that the supposed underlying form of a morpheme is indeed directly observed in some surface form. Nonetheless, such a principle cannot be an absolute condition on the relation between underlying and surface forms, that is, it cannot be a principle in the theory of grammar. Recall from chapter 4 that in Palauan, all unstressed vowels become schwa, and underlying forms of roots may contain two full vowels, for example /daŋob/ "cover", /teʔib/ "pull out", /ŋetom/ "lick". We are justified in concluding that the first vowel in /daŋob/ is /a/ because it is actually pronounced as such in [mə-dáŋəb] when the first root vowel is stressed, and we are justified in concluding that the second vowel is /o/ because that is how it is pronounced in [dəŋóbl]. Although each hypothesized underlying vowel can be pronounced in one surface variant of the root or another, no single surface form ac-

[1] Principles to this effect were proposed in the theory of Natural Generative Phonology, cf. Vennemann 1974.

tually contains both vowels in their unreduced form: the hypothesized underlying form /daŋob/ is never pronounced as such, thus our analysis of Palauan is a counterexample to the excessively restrictive statement (1). Similar examples come from English (cf. the underlying stem /tɛlɛgræf/ which explains the surface vowel qualities in [tɛ́ləgrǽf] and [təlɛ́grəf-ìy]) and Tonkawa (cf. /picena/ which is justified based on the surface forms *picna-n-oʔ* and *we-pcen-oʔ*). Condition (1) also run into problems in Yawelmani (chapter 7), which has a rule shortening a long vowel before a cluster of two consonants, and another rule inserting *i* after the first of three consonants. The two rules apply in stems such as /ʔa:ml/, so that epenthesis turns /ʔa:ml-hin/ into [ʔa:mil-him], and shortening turns /ʔa:ml-al/ into [ʔamlal]. The problem for (1) is that /ʔa:ml/ can never be pronounced as such, since either the vowel is shortened, or *i* is inserted.

Rather than abandon the enterprise of doing phonology in these languages out of misguided allegiance to an a priori assumption about the relationship between underlying and surface forms, we might consider a weaker constraint, which allows underlying forms of morphemes to be composed of segments that are actually pronounced in some attestation of the morpheme, but disallows representations that are more abstract.

(2) The underlying form of a word must contain only segments actually pronounced as such in some related word containing the morpheme

Even this cannot be an absolute requirement. One case that runs afoul of this condition is the case of stem-final voiced stops in Catalan (Chapter 5, problem 4). There is a rule devoicing final obstruents, and another rule spirantizing intervocalic voiced stops. These rules result in alternations such as *sɛk* "dry (masc.)" ~ *sɛkə* "dry (fem.)" from /sɛk/, versus *sek* "blind (masc.)" ~ *seγə* "blind (fem.)" from /seg/. The underlying voiced stop /g/ is not directly attested in any form of the stem /seg/, and thus runs afoul of constraint (2).

Another counterexample to (2) is Kihehe (Chapter 7). That language has a rule assigning H tone to a penultimate vowel that is not also immediately preceded by a H. This rule accounts for the position of the second H tone in words like *kú-kam-íl-a* "to milk for", *kú-kam-il-án-a* "to milk for each other", and the lack of H tone in *kú-kam-a* "to milk" where the penultimate vowel is preceded by a H toned vowel. Surface forms such as *kú-kam-y-á* "to cause to milk" and *kú-kam-w-á* "to be milked" would seem to be exceptions, but actually they follow the general pattern perfectly, as long as we recognize that the underlying forms are /kú-kam-i-a/ and /kú-kam-u-a/. Given those underlying forms, the H is regularly assigned to the penultimate vowel giving *kú-kam-í-a* and *kú-kam-ú-a*, and then the high vowels become glides before a vowel, causing the H tone to be transfered to the final vowel. The important point about these examples is that the assumed vowels of the causative and passive are never surface vowels: they appear only as glides, since

by quirks of Kihehe morphology, the morphemes *-i* and *-u* are always followed by a vowel suffix, so they always undergo glide formation

1.3. Case studies in abstract analysis

We will look in depth at two cases of abstract phonological analysis, one from Kimatuumbi and one from Sanskrit, where abstract underlying forms are well-motivated; these are contrasted with some proposals for English, which are not well-motivated. Our goal is to see that the problem of abstractness is not about the formal phonetic distance between underlying and surface forms, but rather it involves the question of how strong the evidence is for positing an abstract underlying representation.

Abstract mu in Kimatuumbi. Kimatuumbi provides an example of an abstract underlying representation, involving an underlying vowel which never surfaces as such. In this language, the noun prefix which marks nouns of lexical class 3 has a number of surface realizations such as [m], [n], [ŋ] and [mw], but the underlying representation of this prefix is /mu/, despite the fact that the prefix never actually has that surface manifestation with the vowel *u*.

We begin with the effect which nasals have on a following consonant. Sequences of nasal plus consonant are subject to a number of rules in Kimatuumbi, and there are two different patterns depending on the nature of the nasal. One such nasal is the prefix /ñ-/, marking nouns and adjectives of grammatical class 9. When this prefix comes before an underlyingly voiced consonant, the nasal assimilates in place of articulation to that consonant, by a general rule that all nasals agree in place of articulation with an immediately following consonant.

(3)	*adjective* (cl. 9)	*verb*	
	m-bomwáaná	bómwaana	"pointlessly destroy"
	ŋ-golóká	góloka	"be straight"
	ñ-ǰilúká	ǰíluka	"fall down"

When added to a stem beginning with a nasal consonant, the nasal deletes.

(4)	*adjective* (cl. 9)	*verb*	
	mamáandwá	mámaandwa	"nail"
	mimíná	mímina	"spill"
	namátá	námata	"be sticky"

The prefix /ñ/ causes a following voiceless consonant to become voiced.

(5)	*adjective* (cl. 9)	*verb*	
	n-dɪníká	tínɪka	"cut"
	n-demá.á	téma	"chop"
	ñ-ǰapíičá	čápiiča	"be clean"

Finally, /ñ/ causes a following glide to become a voiced stop.

(6)	*adjective* (cl. 9)	*verb*	
	ñ-ǰukútá	yúkuta	"be full"
	ŋ-gwaá.á	wá	"die"
	ŋ-gwɪkílyá	wíkɪlya	"cover"

We know that the prefix is underlyingly /ñ/ because that is how it surfaces before vowel-initial adjectives such as *ñ-epeési* "light (cl. 9)", *ñ-iípi* "short (cl. 9)".

Different effects are triggered by the nasal of the prefix /mu/ which marks 2 pl. subjects on verbs. This prefix has the underlying form /mu/, and it can surface as such when the following stem begins with a consonant.

(7)	mu-buundíke	"you should store"
	mu-laabúke	"you should breakfast"
	mu-ǰiiŋgí	"you should enter"
	mu-goóñje	"you should sleep"

A rule deletes the vowel *u* preceded by *m* when the vowel precedes a consonant, and this rule applies optionally in this prefix. Before a stem beginning with a voiced consonant, deletion of the vowel results in a cluster of a nasal plus a consonant, and *m* causes nasalization of the following consonant (compare the examples in (7) where the vowel is not deleted).

(8)	m-muundíke	"you should store"
	n-naabúke	"you should breakfast"
	ñ-ñiiŋgí	"you should enter"
	ŋ-ŋoóñje	"you should sleep"

This reveals an important difference between the two sets of post-nasal processes. In underlying nasal+C sequences such as /ñ-bomwáaná/ → *m-bomwáaná* "destroyed (cl. 9)", the nasal only assimilates in place of articulation to the following C, but in nasal+C sequences derived by deletion of *u*, the prefixal nasal causes nasalization of a following voiced consonant.[2]

[2] The reason for this difference, as shown in Odden 1996, is that /mu/ first becomes a syllabic nasal *m̩*, and nasalization takes place after a syllabic nasal.

Another difference between /ñC/ versus /muC/ is evident when the prefix /mu/ comes before a stem beginning with a nasal consonant. The data in (9) show that when *u* deletes, the resulting cluster of nasals does not undergo nasal deletion

(9)	mu-mímiine	m-mímiine	"you (pl.) spilled"
	mu-nóolite	n-nóolite	"you (pl.) sharpened"
	mu-ŋáandite	ŋ-ŋáandite	"you (pl.) played"

In comparison, class 9 /ñ-mimíná/ with the prefix /ñ/ surfaces as *mimíná* "spilled (cl. 9)", having undergone degemination.

A third difference between /ñ+C/ versus /mu+C/ emerges with stems that begin with a voiceless consonant. As seen in (10), /mu/ simply assimilates in place of articulation to the following voiceless consonant.

(10)	mu-paánde	m-paánde	"you should plant"
	mu-teleké	n-teleké	"you should cook"
	mu-čoné	ñ-čoné	"you should sew"
	mu-kalaáŋge	ŋ-kalaáŋge	"you should fry"

Remember, though, that /ñ/ causes a following voiceless consonant to become voiced, so /ñ-tɪníká/ → *ndɪníká* "cut (cl. 9)".

Finally, /mu/ causes a following glide to become a nasal.

(11)	mu-wɪkɪlí	ŋ-ŋwɪkɪlí	"you should cover"
	mu-yɪkɪtí	ñ-ñikɪtí	"you should agree"

Underlying /ñ/, on the other hand, causes a following glide to become a voiced stop, cf. /ñ-wɪkílyá/ → *ŋ-gwɪkílyá* "covered (cl. 9)".

The differences between /ñ/ and /mu/ go beyond just their effects on following consonants: they also have different effects on preceding and following vowels. In the case of /mu/, the preceding vowel lengthens just in case *u* deletes.

(12)	iwɪkɪlyó mu-toóle	"you should take the cover"
	iwɪkɪlyóo n-toóle	id.
	ñuúmba mu-bomwaáne	"you should destroy the house"
	ñuúmbaa m-momwaáne	id.

On the other hand, /ñ/ has no effect on the length of a preceding vowel.

(13)	iwɪkɪlyo m-bwapwáaniká	"broken cover"
	ñumbá m-bomwáaná	"destroyed house"

Finally, /ñ/ surfaces with a palatal nasal before a vowel, and the length of the following vowel is not affected (the next vowel is long only if it is underlyingly long). But the 2 pl. prefix /mu/ surfaces as [mw] before a vowel due to a process of Glide Formation, and the following vowel is always lengthened.

(14)		*stem*		
	/ñ/	/iípi/	ñ-iípi	"short (cl. 9)"
		/epeési/	ñ-epeési	"light (cl. 9)"
	/mu/	/ɩɩmba/	mw-ɩímb-e	"you should dig"
		/eleew/	mw-eeleéw-e	"you should understand"

In summary, a number of properties distinguish /mu/ from /ñ/. Apart from the important fact that positing these different underlying representations provides a phonological basis for distinguishing these effects, our choices of underlying forms are uncontroversial, because the posited forms of the prefixes are actually directly attested in some surface variant: recall that the 2 pl. verbal subject prefix /mu/ can actually be pronounced as [mu], since deletion of /u/ is optional for this prefix.

Now we are in position to discuss a prefix whose underlying representation can only be inferred indirectly. The prefix for class 3 nouns and adjectives is underlyingly /mu/, like the 2 pl. verbal subject prefix. Unlike the verb prefix, the vowel /u/ of the class 3 noun prefix always deletes, and /mu/ never appears as such on the surface — its underlying presence can only be inferred indirectly.[3] A strong indication that this prefix is underlyingly /mu/ is the fact that it has exactly the same effect on a following consonant as the reduced form of the subject prefix *mu* has. It causes a voiced consonant to become nasalized.

(15)	*infinitive*	*adjective* (cl. 3)	
	búundika	m-muúndiká	"store"
	láabuka	n-naábuká	"breakfast"
	ǰíiŋgya	ñ-ñiíŋgyá	"enter"
	góoñja	ŋ-ŋoóñjá	"sleep"

It forms a geminate nasal with a following nasal.

(16)	*infinitive*	*adjective* (cl. 3)	
	máta	m-máta	"plaster"
	múlika	m-múlika	"burn"
	námata	n-námata	"be sticky"

[3] Deletion of *u* is obligatory in this prefix and optional in the subject prefix because subject prefixes have a 'looser' bond to the following stem than lexical class prefixes, which are joined with the stem to form a special phonological domain.

It also does not cause a following voiceless consonant to become voiced.

(17)	*infinitive*	*adjective* (cl. 3)	
	páanda	m-paándá	"plant"
	téleka	n-teléká	"cook"
	čóna	ñ-čoná.á	"sew"
	kálaaŋga	ŋ-kaláaŋgá	"fry"

Another reason to believe that this prefix is underlyingly /mu/ is that when it comes before a stem beginning with a vowel, the prefix shows up as [mw] and the following vowel is lengthened.

(18)	*infinitive*	*adjective* (cl. 3)	
	álibika	mwaalíbiká	"break"
	épuka	mweepúká	"avoid"
	íɩmba	mwɩímbá	"dig"
	ótoka	mwootóká	"puncture"

Under the hypothesis that the class 3 prefix is /mu/, we automatically predict that the prefix should have this exact shape before a vowel, just as the uncontroversial prefix /mu/ marking 2 pl. subject has.

Finally, the data in (19) show that this prefix has the same effect of lengthening the preceding vowel as the 2 pl subject prefix has.

(19)	mwoógo	"cassava"	mwoogoo m-moú	"rotten cassava"
	mpɩlá	"football"	mpɩláa m-puwáaniká	"broken football"
	nkóta	"sweets"	nkotáa n-noga.á	"good sweets"
	nkwá	"spear"	nkwáa n-kúlú	"big spear"

The only reasonable assumption is that this prefix is underlyingly /mu/, despite the fact that the vowel *u* never actually appears as such. Direct attestation of a hypothesized underlying segment does provide very clear evidence for the segment in an underlying form, but underlying forms can also be established by indirect means, such as showing that one morpheme behaves in a manner parallel to some other which has a known and uncontroversial underlying form.

Abstract /ai/ and /au/ in Sanskrit. A significantly more abstract representation of the mid vowels [e:,o:] is required for Sanskrit. These surface vowels derive from the diphthongs /ai/, /au/, which are never phonetically manifested in the language. The surface vowels (syllabics) and diphthongs of Sanskrit are in (20).

(20) a i u r̩ l̩ a: e: i: o: u: r̩: a:i a:u

Two things to be remarked regarding the inventory are that while the language has diphthongs with a long first element *a:i, a:u*, it has no diphthongs with a short first element. Second, the mid vowels only appear as long, never short. These two facts turn out to be related.

One phonological rule of the language fuses identical vowels into a single long vowel. This process operates at the phrasal level, so examples are quite easy to come by, simply by combining two words in a sentence.

(21)	na "not" + asti "is"	→	na:sti	"is not"
	na "not" + a:ste: "he sits"	→	na:ste:	"he doesn't sit"
	nadi: "river" + iwa "like"	→	nadi:wa	"like a river"
	yadi "if" + i:çwarah "lord"	→	yadi:çwarah	"if the lord"
	nadi: "river" + i:çwarah "lord"	→	nadi:çwarah	"lord river"
	sa:dhu "well" + uktam "said"	→	sa:dhu:ktam	"well said"

A second process combines long or short *a* with *i* and *u* (long or short), giving the long mid vowels *e:* and *o:*.

(22)	ca "and" + iha "here"	→	ce:ha	"and here"
	ca "and" + uktam "said"	→	co:ktam	"and said"
	sa: "she" + uktam "said"	→	so:ktam	"she said"
	sa: "she" + i:çwara "O Lord"	→	se:çwara	"she, O Lord"

These data point to an explanation for the distribution of vowels noted in (20), which is that underlying *ai* and *au* become *e:* and *o:*, and that this is the only source of mid vowels in the language. This explains why the mid vowels are all long, and also explains why there are no diphthongs **ai*, **au*.[4]

There is a word-internal context where the short diphthongs *ai* and *au* would be expected to arise by concatenation of morphemes, and where we find surface *e:, o:* instead. The imperfective tense involves the prefixation of *a*-.

(23)	bhar-at-i	"he bears"	a-bhar-at	"he bore"
	tuñj-at-i	"he urges"	a-tuñj-at	"he urged"
	wardh-at-i	"he grows"	a-wardh-at	"he grew"

If the stem begins with the vowel *a*, the prefix *a*- combines with following *a* to give a long vowel, just as *a*+*a* → *a:* at the phrasal level.

(24)	aj-at-i	"he drives"	a:j-at	"he drove"
	añc-at-i	"he bends"	a:ñc-at	"he bent"

[4] There is also a rule shortening a long vowel before another vowel at the phrasal level, which is why at the phrasal level /a:/ plus /i/ does not form a long diphthong [a:i].

When the root begins with the vowels *i*, *u*, the resulting sequences *ai*(:), *au*(:) surface as long mid vowels

(25)	il-at-i	"he is quiet"	e:l-at	"he was quiet"
	i:kṣ-at-i	"he sees"	e:kṣ-at	"he saw"
	ukṣ-at-i	"he sprinkles"	o:kṣ-at	"he sprinkled"
	ubj-at-i	"he forces"	o:bj-at	"he forced"

These alternations exemplify the rule where /ai,au/ → [e:,o:].

The have shown that /a+i, a+u/ surface as [e:,o:], so now we will concentrate on the related conclusion that [e:,o:] derive from underlying /ai, au/. One argument supporting this conclusion is a surface generalization about vowel combinations, that when *a* combines with what would surface as word initial *o:* or *e:*, the result is a long diphthong *a:u, a:i*.

(26)	a.	ca "and" + o:kṣat "he sprinkled"	→	ca:ukṣat	"and he sprinkled"
		ca "and" + e:kṣat "he saw"	→	ca:ikṣat	"and he saw"
	b.	ca "and" + ukṣati "he sprinkles"	→	co:kṣati	"and he sprinkles"
		ca "and" + i:kṣati "he sees"	→	ce:kṣati	"and he sees"

This fusion process makes sense given the proposal that [e:] and [o:] derive from /ai/ and /au/. The examples in (26b) remind us that initial [e:,o:] in these examples transparently derive from /a+i/, /a+u/, because in these examples /a/ is the imperfective prefix and the root vowels *u,i* can be seen directly in the present tense. Thus the underlying forms of [ca:ukṣat] and [ca:ikṣat] are [ca#a-ukṣat] and [ca#a-ikṣat]. The surface long diphthong derives from the combination of the sequence of *a*'s into one long *a:*.

Other evidence argues for deriving surface [e:,o:] from /ai,au/. There is a general rule where the high vowels /i,u/ surface as the glides [y,w] before another vowel, which applies at the phrasal level in the following examples.

(27)	e:ti "he comes" + ṛṣi "seer"	→	e:ty ṛṣi
	yadi "if" + aham "I"	→	yady aham
	yadi "if" + a:ditya:h "sons of Aditi"	→	yady a:ditya:h
	e:ti "she comes" + uma: "Uma:"	→	e:ty uma:
	bhawatu "let it be" + i:çwarah "lord"	→	bhawatw i:çwara
	sadhu "well" + e:ti "he comes"	→	sadhw e:ti

The mid vowels [e:,o:] become [ay, aw] before another vowel.[5]

(28)	prabho: "O Master" + e:ti "he comes"	→	prabhaw e:ti
	wane: "in the forest" + a:ste: "he sits"	→	wanay a:ste:
	wane: "in the forest" + e:ti "he comes"	→	wanay e:ti
	prabho: "O Master" + o:kṣat "he sprinkled"	→	prabhaw o:kṣat

This makes perfect sense under the hypothesis that [e:,o:] derive from /ai,au/. Under that hypothesis, /wanai#a:stai/ undergoes glide formation before another vowel (just as /yadi#aham/ does), giving [wanay#a:ste:].

Abstractness in English. We now consider cases where abstract analyses have been proposed, but where the legitimacy of these analyses has been seriously questioned: since the main point being made here is that abstract analyses can be well-motivated, it is important to consider what is *not* sufficient motivation for an abstract analysis. A classical case of questionable abstractness is the analysis of English [ɔy] proposed in Chomsky & Halle 1968 (SPE), that [ɔy] derives from /œ̄/. In SPE, English vowels are given a very abstract analysis, with approximately the following relations between underlying and surface representations of vowels, where /ī ū/ and so forth represent tense vowels in the transcription used there.

(29)	/ī/	→	[ay]	/ū/	→	[aw]
	/ē/	→	[iy]	/ō/	→	[uw]
	/ǣ/	→	[ey]	/ɔ̄/	→	[ow]
	/œ̄/	→	[ɔy]	/ā/	→	[ɔʌ]

The first step in arguing for this representation is to defend the assumption that [ay], [aw] [iy], [uw], [ey], [ow] derive from /ī/, /ū/, /ē/, /ō/, /ǣ/ and /ɔ̄/. This claim is motivated by the Trisyllabic Laxing alternation in English which relates the vowels of *div**i**ne ~ div**i**nity* ([ay] ~ [ɪ]), *prof**ou**nd ~ prof**u**ndity* ([aw] ~ [ə]), *s**e**r**e**ne ~ ser**e**nity* ([iy] ~ [ɛ]), *verb**o**se ~ verb**o**sity* ([ow] ~ [ɔ]) and *s**a**ne ~ s**a**nity* ([ey] ~ [æ]). These word pairs are assumed to be morphologically related, so that both words in the pair involve a common root: the question is what the underlying vowel of the root is. It is assumed that tense vowels undergo a process known as Vowel Shift, which rotates a tense vowel's height one degree upward — low vowels become mid, mid vowels become high, and high vowels become low. Another process that is relevant is Diphthongization, which inserts a glide after a tense vowel agreeing in backness with that vowel. By those rules (and a few others), /sǣn/ becomes [sēyn], /serēn/ becomes [sərīyn] and /divīn/ becomes [dəvayn]. By the Trisyllabic Laxing rule, when a tense vowel precedes the penultimate syl-

[5] An optional rule, most usually applied, deletes the glide in this context, giving a vowel sequence.

lable of the word the vowel become lax, which prevents the vowel from shifting in height (shifting only affects tense vowels). Accordingly, [dəvayn] and [dəvɪnətiy] share the root /dəvīn/. In [dəvayn], the tense vowel dipthongizes to [dəvīyn], which undergoes Vowel Shift. In /dəvīn-iti/, the vowel /ī/ instead undergoes Trisyllabic laxing, and therefore surfaces as [ɪ].

In this way, SPE reduces the underlying vowel inventory of English to /ī/ /ū/ /ē/ /ō/ /ǣ/ /ā/ /ɔ̄/, plus the diphthong /ɔy/. Having eliminated most of the diphthongs from underlying representations, we are still left with one diphthong. In addition, there is an asymmetry in the inventory, that English has three out of four of the possible low tense vowels, lacking a front round vowel [œ̄]. It is then surmised that this gap in the system of tense vowels, and the remaining diphthong, can both be explained away simultaneously, if [ɔy] derives from underlying /œ̄/. Furthermore, given the system of rules in SPE, if there were a underlying vowel /œ̄/, it would automatically become [ɔy].

Briefly, /œ̄/ undergoes diphthongization to become *œ̄y* because *œ̄* is a front vowel and the glide inserted by dipthongization has the same backness as the preceding tense vowel. The vowel *œ̄* is subject to backness readjustment which makes front low vowels [+back] before glides (by the same process, *æy* which derives from /ī/ by Vowel Shift becomes [ay]). Since hypothesized /œ̄/ does not become *[ö], and must remain a low vowel in order to undergo backness adjustment, Vowel Shift must not apply to /œ̄/. This is accomplished by constraining the rule to not affect a vowel whose values of backness and roundness are different.

What constitutes a valid motivation? This analysis of [ɔy] is typical of highly abstract phonological analyses advocated in early generative phonology, where little concern was given to maintaining a close relation between surface and underlying forms. The idea of deriving [ɔy] from /œ̄/ is not totally gratuitous, since it is motivated by a desire to maintain a more symmetrical system of underlying representations. But the goal of producing symmetry in underlying representations cannot be maintained at all costs, and whatever merits there are to a symmetrical, more elegant underlying representation must be balanced against the fact that abstract underlying forms are inherently difficult for a child to learn. Put simply, the decision to analyse English vowels abstractly is justified only by an esoteric philosophical consideration — symmetry — and we have no evidence that this philosophical perspective is shared by the child learning the language. If achieving symmetry in the underlying form isn't a sufficient reason to claim that [ɔy] comes from /œ̄/, what would motivate an abstract analysis?

Abstractness can easily be justified by showing that it helps to account for phonological alternations, as we have seen in Palauan, Tonkawa, Kimatuumbi, Kihehe and Sanskrit. No such advantage accrues to an abstract analysis of [ɔy] in English. The only potential alternations involving [ɔy] are a few word pairs of questionable synchronic relatedness such as *joint ~ juncture, point ~ puncture*, *ointment ~ unctious*, *boil ~ bullion, joy ~ jubilant, soil ~ sully, choice ~ choose,*

voice ~ vociferous, royal ~ regal. This handful of words gives no support to the abstract hypothesis. If underlying /œ̄/ were to undergo laxing, the result should be the phonetically nonexistant vowel [œ], and deriving the mixture of observed vowels [ʌ], [ʊ], [uw], [ow], or [iy] from [œ] would require rather ad hoc rules. The hypothesized underlying vowel system /ī ū ē ō ǣ ɔ̄ œ̄/ runs afoul of an otherwise valid implicational relation in vowel systems across languages, that the presence of a low front rounded vowel (which is one of the more marked vowels in languages) implies the presence of non-low front round vowels. This typological implicational principle would be violated by this abstract analysis of English, which has no underlying /ü, ö/: in other words, idealisations about underlying forms can conflict.

An important aspect of the argument for [ɔy] as /œ̄/ is that there is independent motivation for the rules that would derive [ɔy]: but the argument for those rules is not ironclad, in particular the Vowel Shift rule. The motivation for Vowel Shift in synchronic English hinges on alternations of the type *div**i**ne ~ div**i**nity*, *prof**ou**nd ~ prof**u**ndity*, and these alternations are restricted and unproductive in English (unlike the phonological alternations in the form of the plural suffix). A consequence of the decision to analyse all cases of [ay] as deriving from /ī/ is that many other abstract assumptions had to be made to explain the presence of tense vowels and diphthongs in unexpected positions (such as before the penultimate syllable). To acount for the contrast between *contrite ~ contrition* where /ī/ becomes lax and *t* → *š*, versus *right ~ righteous* where there is no vowel laxing and *t* → *č*, it was claimed that the underlying form of *right* is /rixt/, and rules are developed whereby /ixC/ → [ayC]. Abstract /x/ is called on to explain the failure of Trisyllabic Laxing in the word *nightingale*, claimed to derive from /nixtVngǣl/. To explain the failure of Trisyllabic Laxing in words like *rosary*, it is assumed that the final segment is /y/ and not /i/, viz. /rɔ̄sVry/. Other examples of abstract analysis in SPE are that the contrast between *veto* (with no flapping of /t/ and a secondary stress on the final vowel) vs. *motto* (with flapping of /t/ and no secondary stress) can be predicted by positing different underlying vowels — /mɔto/ vs. /vētɔ/, even though the vowel qualities of the two words are surface identical. Words such as *relevance* are claimed to contain an abstract non-high front glide, whose function is to trigger assibilation of /t/ and then delete, so *relevance* would derive from /relevant^{e}/, /^{e}/ representing a non-syllabic non-high front vocoid (a segment not attested in any language to date).

It is not sufficient to simply reject these analyses as being too abstract, since that would amount to circularly answering the abstractness controversy by fiat. We need to pair that rejection with an alternative analysis that states what we *do* do with these words, and this reanalysis formed a significant component of post-SPE research. More importantly, we need to identify the methodological assumptions that resulted in these excessively abstract analyses. One point which emerged from this debate is that a more conservative stance on word-relatedness is called for. A core assumption in doing a phonological analysis is that we establish and underlying representations whereby related words can be derived from a uni-

fied source by the application of phonological rules. The concept 'related word' needs to be scrutinized carefully, because liberally assuming that all 'related words' have common underlying forms can yield very abstract analyses.

Word Relatedness. Consider word pairs such as "happy" / "glad", "tall" / "long" and "young" / "old". Such words are "related", in having similar semantic properties, but they are not morphologically related, and no one would propose deriving both "happy" and "glad" from a single underlying root. Nor would anyone propose treating such pairs as *brain / brandy, pain / pantry, grain / grant* as involving a single underlying root, since there is no semantic relation between members of the pair. Pairs such as "five" / "punch", "crane" / "cranberry" are related historically, but the connection between the words is known only to students of the history of English. The words "father" and "paternal" are related both semantically and phonologically, as are "brother" and "fraternal", or "mother" and "maternal", but this does not mean that we can derive "father" and "paternal" from a single underlying root which is part of the synchronic grammar of English. It may be tempting to posit relations between "choir" and "chorus", "foil" and "folly", "shield" and "shelter", or "hole" and "hollow", but again these do not represent processes of word formation which are part of modern English grammar.

It is uncontroversial that words such as "cook" and "cooked" or "book" and "books" are morphologically related: the words share common roots "cook" and "book", and there are highly productive morphological processes which derives plurals of nouns and past tense forms of verbs. Any analysis of English word formation which failed to capture the formal relatedness of these words would be inadequate, and an analysis of word structure which required such regular present / past or singular / plural pairs to be independently listed in the lexicon would be little better than a theory of syntax which required phrases like "Tom slept" and "Sue slept" to be independently listed. The relation between "tall" and "tallness" or "compute" and "computability" is similarly undeniable. In such cases, the syntactic and semantic relations between the words is transparent and the morphological processes represented are regular and productive.

Some morphological relations are not so clear: -*ment* attach to some verbs such as *bereavement, achievement, detachment, deployment, payment, placement, allotment*, but it is not fully productive since we don't have **thinkment, *takement, *allowment, *intervenement, *computement, *givement*. There are a number of verb / noun pairs like *explain / explanation, decline / declination, define / definition, impress / impression, confuse / confusion* which involve affixation of -(*Vt*)-*ion*, but is not fully productive as shown by the nonexistence of pairs like *contain / *contanation, refine / *refination, stress / *stression, impose / *imposion, abuse / *abusion*. Since it is not totally predictable which -*ion* nouns exist or what their exact form is, it is plausible that these words are just listed in the lexicon. If each word is listed in the lexicon, there is no reason why the words could not have slightly different underlying forms.

It is thus legitimate to question whether pairs such as *verbose / verbosity, profound / profundity, divine / divinity* represent cases of synchronic derivation from a single underlying root, rather than being phonologically and semantically similar pairs of words, which are nevertheless entered as separate and formally unrelated lexically items. The question of how to judge formal word-relatedness remains controversial to this day, and with it, many issues pertaining to phonological abstractness.

2. Independent Evidence: Historical Restructuring

Kiparsky's seminal 1968 paper 'How Abstract is Phonology' raises the question whether limits on abstractness are possible and desirable. Kiparsky's particular concern is the postulation of segments which are never realized in the language, cases where the language is assumed to have an underlying distinction between two segments which are always phonetically merged. A classic example of this kind of abstractness is Hungarian, which has a vowel harmony rule where suffix vowels agree with the preceding vowel in backness, e.g. *ha:z-am* "my house", *fül-em* "my ear", *ke:s-em* "my knife", *vi:z-em* "my water". A relatively small number of roots with the front vowels *i:, i* or *e:* always have back vowels in suffixes, e.g. *he:j-am* "my rind", *nyi:l-am* "my arrow". The abstract analysis proposed for these roots is that they have underlying back vowels /ɨ/, /ɨ:/ and /ə:/, and a rule fronts these vowels neutralizing /ɨ/, /ɨ:/ with /i/, /ɨ:/ and /ə:/ with /e:/. This move makes thse roots phonologically regular. The reasoning is that since these surface front vowels seem to act as though they are back vowels, in terms of the vowel harmony system, maybe they really *are* back vowels at a deeper level.

Kiparsky terms this kind of analysis **absolute neutralization**, to be distinguished from **contextual neutralization**. In contextual neutralization, the distinction between two underlying segments is neutralized in some contexts, but is preserved in others. Final devoicing in Russian is contextual neutralization because in the words /porok/ and /porog/, the distinction between *k* and *g* is neutralized in the nominative singular [porok], but is maintained in genitive [poroka] vs. [poroga]. With absolute neutralization, the distinction is eliminated in all contexts, and thus in Hungarian, /ɨ/ is always neutralized with /i/. Kiparsky argues that while contextual neutralization is common and has demonstrable psychological reality, absolute neutralization is a theoretically constructed fiction.

In arguing against the possibility of absolute neutralization in a language, Kiparsky faces the challenge that a number of cases of such abstractness had been postulated, so good reasons for rejecting those analyses must be found. Kiparsky focuses on the extent to which the psychological reality of theoretical constructs can be measured — this is an important consideration since linguistic theories are usually intended to be models of the psychological processes underlying linguistic behavior. The problem is that it is impossible to directly test whether linguistic constructs are psychologically valid by any simple or obvious tests. Linguistic

properties are highly abstract, and not easily tested in the same way that one can experimentally test the ability to perceive touch or distinguish colors or sounds. Kiparsky argues that one can, in certain circumstances, use the pattern of language change as a theory-external test of linguistic theories. It is argued that evidence from historical sound change can provide just such a test.

An abstract phonological distinction cannot be justified on the basis of the fact that two historically distinct sounds merge in in the history of a language, so even if is shown that Hungarian *he:j* "rind" and *nyi:l* "my arrow" derive from earlier **hə:j* and **nyɨ:l*, this would not be evidence for an abstract underlying form in modern Hungarian. A child learning the language has no access to this kind of historical information. What Kiparsky points out is that one can inspect a later stage of a language to gain valuable insights into the analysis of a language that was actually given at an earlier stage of the language, and then adduce general principles about grammars based on such independent evidence.

2.1. Yiddish final devoicing

The history of Yiddish devoicing provides one important example of historical evidence bearing on the abstractness controversy. In the oldest forms of German, represented by Old High German, there was no restriction against word-final voiced consonants, so Old High German had words like *tag* 'day' ~ *tag-a* 'days', *gab* 'he gave' ~ *gābumes* 'we gave', *sneid* 'he cut' ~ *snīdan* 'to cut', *hand* 'hand' , *land* 'land'. Between 900 and 1200 in the Middle High German period, a rule of devoicing was added, which resulted in *tac* 'day' ~ *tage* 'days', *gap* 'he gave' ~ *gāben* 'we gave', *sneit* 'he cut' ~ *snīden* 'to cut', *hant* 'hand' ~ *hende* 'hands', *wec* 'road' ~ *weges* 'roads'.

Around this time, Yiddish began to develop as a language separate from German, and would have shared this devoicing rule. Devoicing of final consonants in Yiddish is attested in manuscripts from the 13th century where "day" is written <tak>, using the letter *kuf* [k] and not *gimel* [g]. In some dialects, such as Central and Western Yiddish, this devoicing persists up to today, where you find *tak* "day" ~ *tag-n* "days", *lant* "land" ~ *lend-ər* "lands", with the stem final voiced consonants of /tag/, /land/ undergoing final devoicing in the singular. In some dialects such as the Northeastern dialect of Yiddish, the devoicing rule was lost from the grammar, so that dialect has *tog* "day" ~ *tog-n* "days", where the originally voiced consonant actually re-appears as voiced. This process where an earlier sound change is dropped from the grammar is known as **reversal of sound change**.

There are what appear to be mysterious exceptions to the generalization that original voiced consonants are restored in Northeastern Yiddish. One such case is the word *gelt* "money", which derives historically from *geld* with a voiced consonant. The explanation for the different treatments of *gelt* and *tag*, words which both ended with voiced consonants at earlier stages of the language, is based on differences in the presence or absence of phonological alternations within the

paradigm of a word. In the case of *tag*, the plural form had a suffix -*n*, and so while the singular was subject to devoicing, the plural was not: this word had the paradigmatic alternations [tak] ~ [tagn]. On the basis of these alternations, a child learning the language would have no problem discovering that the underlying form of the stem is /tag/. It is expected that once the final devoicing rule is lost, the underlying form /tag/ resurfaces since there is no longer a devoicing rule.

In the word *gelt*, the situation was different. There was no inflectional ending which followed this particular noun. At the earliest stages of the language, a child learning the language only encounters [geld], and there would be no basis for assuming that the underlying form is anything other than /geld/. When the devoicing rule was added to the grammar, the pronunciation of the word changed to [gelt]. Since this particular consonant was always word-final, the devoicing rule would have always applied to it, so the stem only had the phonetic form [gelt]. Although either /geld/ or /gelt/ as underlying form would yield the surface form [gelt], there is no reason to assume that the surface and underlying forms are different. A priori criteria may support one decision or the other, but what we need to know is, what independent test tells us that our reasoning is correct? The loss of the devoicing rule provides exactly the needed empirical test: it allows us to know what underlying form Yiddish-learning children must have assumed at this earlier stage. Knowing the actual underlying form provides an important insight into the learning strategies that children make during language acquisition.

When the final devoicing rule was added and there are no phonetic alternations in *gelt*, a child would have no reason to assume that the underlying form of the word is anything other that /gelt/. The child never hears *geld*, and has no reason to think that the underlying form is different from the surface form. At an even later stage of the language, the rule of final devoicing is dropped from the grammar of certain dialects. This allows the underlying and historically original voiced consonant of *tag* to be pronounced again, since it is no longer subject to devoicing and thanks to the paradigmatic *k* ~ *g* alternation the underlying form was established as being /tag/. This rule loss has no effect on *gelt*, since despite being derived historically from a voiced consonant, the final consonant of the stem had been reanalysed as being an underlying voiceless consonant — a reanalysis which is predicted by the presumption that an underlying form is different from the surface form only if there is good reason for assuming so. Because there are no surface alternations for this word, there was no reason to assume an abstract underlying form.

Another important kind of exception to the reversal of devoicing is seen in the adverb *avek* "away". This word was originally *aveg*, with a voiced consonant. This adverb also had no inflected relatives which allowed the underlying voicing of the final consonant to be unambiguously determined, so once the devoicing rule is added to the grammar, it was impossible to determine whether the underlying form was /avek/ or /aveg/. Again, starting from the assumption that underlying forms do not deviate from surface forms without reason, there is no reason to assume that phonetic [avek] derives from anything other than /avek/, once the word

is actually pronounced [avek]. The fact that the underlying form is directly revealed as *avek* in the dialects which dropped devoicing supports this decision.

The example also reveals something interesting about what might (but does not) constitute a 'reason' for abstractness. The adverb *avek* is historically related to the noun *veg* "way". The voicing of the last consonant in the noun stem can be recovered within the paradigm given the earlier alternations *vek* "way" ~ *vegn* "ways", because the singular and plural forms of the noun are clearly related to each other. The evidence from the plural noun had no impact on the child's decisions about the underlying form for the adverb, since there is no clear synchronic connection between the adverb and the noun — there is no general process deriving nouns and adverbs from a unified source, and no good reason to see the kind of connection between the noun "way" and the adverb "away" that would warrant deriving the words from a single underlying root. The divergence of the words *veg* and *avek* in the history of Yiddish points out that one cannot gratuitously assume that any two phonetically and semantically similar words are actually derived from a single underlying form.

2.2. Byelorussian and Ukranian palatalization

Similar restructuring and rule loss is found in the history of Ukranian and Byelorussian. In the dialects of proto-Indo-European which developed into proto-Slavic, certain verbs suffixed *-y-* in the present tense, so inflectional paradigms would have included forms such as *sid-y-õ* "I sit", *sid-e:-ti* "to sit", *beg-y-õ* "I run", *beg-i-ti* "to run", *plak-y-õ* "I cry", *plak-a-ti* "to cry". In later proto-Slavic, a number of palatalization processes were added, one including one turning *dy* into *ǰ* and *gy* into *ž*. With the addition of palatalization, a child learning the language would encounter phonetic forms such as *sǐǰ-u* ~ *sid-iti*, *bež-u* ~ *beg-i-ti* and *plač-u* ~ *plak-a-ti*. The paradigmatic alternations *ǰ* ~ *d* in some roots and *ž* ~ *g* in others would have resulted in a mildly abstract analysis of the palatals in *sǐǰu* and *bižu* as deriving from /d/ and /g/, with which they alternate in the verbal paradigm.

Much later in the development of Slavic, a rule was added to the grammars of the Western Slavic languages (Russian, Byelorussian, and Ukranian), where the voiced affricate *ǰ* spirantizes to *ž*. This changed the phonetic realization of the verbal alternations, so that children heard *siž-u* ~ *sid-iti* and *biž-u* ~ *big-i-ti*. Again, the pattern of alternations within the paradigm still provides the basis for positing that *sižu* has an underlying voiced alveolar stop and *bižu* has a voiced velar stop. Moreover, the fact that the voiceless stops *k*, *t* appear as affricates, not fricatives (cf. *plač-u* "I cry" ~ *plak-a-ti* "to cry", *moloč-u* "I thresh" ~ *molot-i-ti* "to thresh") indicates that spirantization is not a direct result of the palatalization process, which is to say, this change does not reflect a modification of palatalization itself, but indicates a spirantization ot voiced affricates.

The above scenario also describes the state of affairs in modern Russian. However, there were two further developments in Byelorussian and Ukranian.

First, /g/ became γ in Byelorussian, *h* in Ukranian. Second, the rule of palatal spirantization was lost, so now Ukranian and Byelorussian have the alternations *sĩǰu*, *sid-iti* and *bižu* ~ *biγ-i-ti*. The analysis of these forms is straightforward. Given these phonetic forms, we can assume that the underlying forms of *sĩǰu* and *bižu* are synchronically /sid-y-u/ and /biγ-y-u/.

Although original *dy* therefore appears as *ǰ* in Ukranian and Byelorussian, and not as *ž* as it does in Russian, not every original *dy* shows up as *ǰ*. The word "middle" *meža* derives originally from **medyo* (ultimately from proto-Indo-European **medhyo*, cognate with English *middle*). Thus proto-Slavic **medyo* is phonologically parallel to **sedyõ:* — why then does *dy* show up as *ǰ* in *sĩǰu* but as *ž* in *meža*? The answer lies in the fact that there was an active pattern of phonological alternation in the verb between *d* and *ǰ* ~ *ž* which allowed the child to know that the underlying form had /dy/, with a stop. On the other hand, the word *medyo* was morphologically isolated —it is not related to other words manifesting the /d/ directly which could have led to the kind of alternations needed to support an abstract phonological alternation. At the stage when the word was pronounced *medya*, there was no reason to assume that the underying form is anything other than *medya*. When palatalization was added to the grammar, the word would have been pronounced *meǰa*, and there would be no reason to assume that the underlying form is other than *meǰa*: we predict that the underlying form had to be restructured, because the child could not know about earlier /medya/. When the rule of palatal spirantization was added, the surface form was pronounced *meža*, leading to further restructuring, so that the underlying and surface forms are identical lacking any evidence for a more abstract underlying representation. When the rule of spirantization is then lost in Ukranian and Byelorussian, we do not expect an affricate to re-emerge in this word, since the underlying form has been restructured so that it has an underlying palatal fricative.

2.3. Historical evidence and the treatment of absolute neutralization

Kiparsky draws two main conclusions from these and similar cases. First, he points out that in lieu of phonological alternations supporting abstractness, the surface and underlying forms should be assumed to be identical: alternations are central to supporting an abstract underlying form. Second, and more controversially, these examples are used in an argument against the psychological reality of absolute neutralization. The argument is as follows. Cases such as Yiddish and Ukranian show the psychological reality of processes of contextual neutralization, since contextual neutralization can be reversed. However, there is no known case where absolute neutralization has been historically reversed: if absolute neutralization had the psychological reality of contextual neutralization, we would expect to find a reversal of absolute neutralization, and we have not. Therefore, putative cases of absolute neutralization lack psychological reality.

Kiparsky proposes that morphemes seem to motivate abstract segments are simply lexical exceptions to the rule in question: they fail to undergo or trigger a rule. For the problematic roots of Hungarian where front vowels seem to trigger back harmony, such as *he:j-am* "my rind", *nyi:l-am* "my arrow", Kiparsky's proposal is that these roots are simply marked as exceptions to vowel harmony and, on the assumption that harmonizing suffixes all contain underlying back vowels, the fact that back vowels appear in suffixes after these roots boils down the the fact that the suffixes have underlying back vowels, and since these roots do not trigger vowel harmony the underlying vowel quality is preserved on the surface.

3. Well-motivated Abstractness

While it is certainly true that some putative processes of absolute neutralization are not well supported and the abstract property only diacritically marks a root as an exception to one rule rule, there are internally well-supported cases of absolute neutralization. Two famous cases are found in Yawelmani discussed by Kisseberth 1969 and Maltese discussed by Brame 1972.

3.1. Yawelmani /u:/

Aspects of Yawelmani have been discussed in chapter 7. Two of the most important processes are vowel harmony and vowel shortening. The examples in (30) demonstrate the basics of vowel harmony: a suffix vowel becomes rounded if it is preceded by a round vowel of the same height.

(30)	*nonfuture*	*imperative*	*dubitative*	*passive aorist*	
	xat-hin	xat-k'a	xat-al	xat-it	eat
	dub-hun	dub-k'a	dub-al	dub-ut	lead by hand
	xil-hin	xil-k'a	xil-al	xil-it	tangle
	k'oʔ-hin	k'oʔ-k'o	k'oʔ-ol	k'oʔ-it	throw

Thus the root vowel /o/ has no effect on the suffixes /hin/ and /it/ but causes rounding of /k'a/ and /al/— and the converse holds of the vowel /u/.

The data in (31) show that long vowels cannot appear before two consonants. These stems have underlying long vowels, and when followed by a consonant-initial affix, the vowel shortens.

(31)	*nonfuture*	*imperative*	*dubitative*	*passive aorist*	
	dos-hin	dos-k'o	do:s-ol	do:s-it	report
	şap-hin	şap-k'a	şa:p-al	şa:p-it	burn
	lan-hin	lan-k'a	la:n-al	la:n-it	hear
	mek'-hin	mek'-k'a	me:k'-al	me:k'-it	swallow
	won-hin	won-k'o	wo:n-ol	wo:n-it	hide

Another class of verb roots has the surface pattern CVCV:C — the peculiar fact about these roots is that the first vowel is always a short version of the second vowel.

(32)	*nonfuture*	*imperative*	*dubitative*	*passive aorist*	
	p'axat-hin	p'axat-k'a	p'axa:t-al	p'axa:t-it	mourn
	ʔopot-hin	ʔopot-k'o	ʔopo:t-ol	ʔopo:t-it	arise from bed
	yawal-hin	yawal-k'a	yawa:l-al	yawa:l-it	follow

There are problematic roots, illustrated in (33), in terms of their pattern of vowel harmony. Although the stem vowel in these examples is a mid vowel, a following non-high vowel does not harmonize — they seem to be exceptions. But worse, a following high vowel *does* harmonize with the root vowel, even though the root mid vowel does not even satisfy the basic phonolgical requirements for harmony, that the vowels must be of the same height. In the examples [wo:ʔuy-hun], [do:lul-hun], the second vowel is an epenthetic vowel, thus these roots underlyingly have the shape CV:CC, parallel to [ʔa:mil-hin] ~ [ʔamlal] "help".

(33)	*nonfuture*	*imperative*	*dubitative*	*passive aorist*	
	c'om-hun	c'om-k'a	c'o:m-al	c'o:m-ut	destroy
	ṣog-hun	ṣog-k'a	ṣo:g-al	ṣo:g-ut	uncork
	wo:ʔuy-hun	wo:ʔuy-k'a	woʔy-al	woʔy-ut	fall asleep
	do:lul-hun	do:lul-k'a	doll-al	doll-ut	climb

A noteworthy property of such roots is that their vowels are always long.

There is another irregularity connected with certain surface mid vowels. The data in (34) illustrates a set of CVCVV(C) roots, where, as we noticed before, the two vowels are otherwise identical. In these verbs, the second long vowel is a non-high version of the first vowel.

(34)	*nonfuture*	*imperative*	*dubitative*	*passive aorist*	
	hiwet-hin	hiwet-k'a	hiwe:t-al	hiwe:t-it	walk
	hibey-hin	hibey-k'a	hibe:y-al	hibe:y-it	bring water
	ʔile:-hin	ʔile-k'	ʔile-l	ʔile-t	fan
	nine:-hin	nine-k'	nine-l	nine-t	get quiet
	ṣudok'-hun	ṣudok'-k'a	ṣudo:k'-al	ṣudo:k'-ut	remove
	t'unoy-hun	t'unoy-k'a	t'uno:y-al	t'uno:y-ut	scorch
	c'uyo:-hun	c'uyo-k'	c'uyo-l	c'uyo-t	urinate

Note too that these stems act irregularly with respect to vowel harmony — they do not trigger harmony in mid vowels, and thus do not act like mid vowels; and they exceptionally trigger harmony in high vowels, as high vowels do.

When you consider the vowels of Yawelmani — [i e a o u e: o: a:] — you see that long high vowels are lacking in the language. The preceding mysteries are solved if you assume, for instance, that "scorch" is /tunu:y/. As such, the root would obey the canonical restriction on the vowels of a bivocalic stem — they are the same vowel — and you expect /u:/ to trigger harmony on high vowels but not on mid vowels, as is the case. A subsequent rule lowers /u:/ to [o:], merging the distinction between underlying /o:/ and /u:/.

The assumption that /u:/ becomes [o:] hence some instances of [o:] derive from /u:/ explains other puzzling alternations. There is a vowel shortening process which applies in certain morphological contexts. One context is the causative, which adds the suffix *-a:la* and shortens the preceding stem vowel.

(35)	*nonfuture plain*	*nonfuture causative*	
	tis-hin	tis-a:la-hin	come out
	hoyo:-hin	hoy-o:lo-hin	have a name
	mek'-hin	mik'-a:la-hin	eat
	c'om-hun	c'um-a:la-hin	destroy

We have seen in (33) that the root [c'o:m] has the phonological characteristics of an abstract vowel, so given the surface-irregular pattern of vowel harmony in *c'om-hun, c'om-k'a* we can see that the underlying vowel must be a high vowel. The fact that the vowel actually shows up as a high vowel as a result of the morphologically conditioned shortening rule gives further support to the hypothesized abstract underlying vowel.

The approach which Kiparsky advocates for absolute neutralization does not work for Yawelmani, in that one cannot simply say that these words are exceptions. Being an exception has a specific meaning: it means that a given morpheme fails to undergo or trigger a rule which it otherwise would undergo. The fact that vowel harmony does not apply in *c'o:m-al* can be handled by saying that *c'o:m-* is an exception to vowel harmony. This root does actually trigger vowel harmony, as shown by *c'o:m-ut*, and this application of vowel harmony is quite problematic, since vowel harmony is applying when the formal conditions of the rule are not even satisfied on the surface. By marking a root as an exception, we are saying that although the root would be expected to undergo a rule, it simply fails to undergo the rule. What we have in Yawelmani is something entirely different — a form is triggering a rule even though it should not. The exceptionality analysis also offers no account of stems such as *c'uyo:-hun*, where the first vowel should have been a copy of the second vowel but instead shows up as a high vowel; nor does the exceptionality account have any way to explain why the 'exceptional' roots show up with high vowels when the root is subject to morphological vowel shortening as in *c'om-hun ~ c'um-a:la-hin*.

3.2. Maltese /ʕ/

Another well-supported case of absolute neutralization comes from Maltese. We begin by outlining some basic phonological processes. In the subsequent section, we consider a number of examples which seem to be inexplicable in terms of the general phonology of the language if underlying forms are limited to just those segments which are directly revealed in pronunciation. However, positing an abstract underlying consonant /ʕ/ in these words provides a very simple account of the data, given the independently motivated phonological rules of the language.

3.2.1. Basic Phonology of Maltese

The examples in (36) examplify two central processes of the language, namely stress assignment and apocope. Disregarding one consonant at the end of the word, the generalization is that stress is assigned to the last heavy syllable — one that ends in a (non-final) consonant or one with a long vowel.

(36)	séna	"year"	sultáan	"king"
	ʔattúus	"cat"	ħdúura	"greenness"
	ħátaf	"he grabbed"	béza ʔ	"he spat"
	ħátf-et	"she grabbed"	béz ʔ-et	"she spat"
	ħtáf-t	"I grabbed"	bzá ʔ-t	"I spat"
	ħtáf-na	"we grabbed"	bzá ʔ-na	"we spat"
	báram	"he twisted"	séra ʔ	"he stole"
	bárm-et	"she twisted"	sér ʔ-et	"she stole"
	brám-t	"I twisted"	srá ʔ-t	"I stole"
	brám-na	"we twisted"	srá ʔ-na	"we stole"

The second group of examples also illustrate apocope, which deletes an unstressed vowel followed by CV. The underlying stems for "grabbed" and "spat" are /ħataf/ and /beza ʔ/, as seen in the 3 sg. masc. form of the verb. Following the stress rule, when the 3 sg. fem. suffix -*et* is affixed, /ħataf-et/ and /beza ʔ-et/ are stressed on the initial syllable, which results in intermediate *ħátaf-et* and *béza ʔ-et*. The intermediate forms are subject to apocope rule (37), which give the surface forms.

(37) $$\underset{[\text{-stress}]}{V} \rightarrow \varnothing \,/\, \_\_\ CV$$

In the case of /ħataf-t/ and /beza ʔ-t/, stress is assigned to the final syllable since that syllable is heavy (only one final consonant is disregarded in making the determination whether a syllable is heavy), and therefore the initial vowel is deleted.

Two other rules of the language are unstressed-vowel reduction and vowel harmony. By the former process, motivated by the data in (38), unstressed *i* reduces to *e*. The underlying form of the 3fs suffix is actually /-it/, and that vowel can be seen directly when the suffix is stressed. The underlying form of *kíteb* is /kitib/. When stress falls on the first syllable of this root, the second syllable reduces to *e*, but when stress is final, the second syllable has *i*.

(38)	hátf-et	"she grabbed"	ħatfít-kom	"she grabbed you (pl)"
	bézʔ-et	"she spit"	bezʔ-ít-l-ek	"she spit at you"
	kíteb	"he wrote"	ktíb-t	"I write"

Thus the following rule is motivated.

(39) $\begin{matrix} \text{i} \\ \text{[-stress]} \end{matrix} \rightarrow \text{[-hi]}$

By vowel harmony, /i/ becomes [o] when preceded by *o*.

(40)	kórob	"he groaned"	kórb-ot	"she groaned"
	šórob	"he drank"	šórb-ot	"she drank"

Surface *kórb-ot* derives from /korob-it/ by applying stress assignment, the vowel harmony in (41), and apocope.

(41) $\text{i} \rightarrow \text{[+round]} \;/\; \begin{matrix} \text{V} \\ \text{[+round]} \end{matrix} \; \text{C}_0 \_\_\_$

Based on examples such as *ħátaf* ~ *ħtáf-t*, we expect any underlying CVCVC stem to have the shape CCVC when a consonant-initial affix is added. This is because the addition of a C-initial affix renders the final stem syllable heavy, so it should be stressed, and since the the first stem vowel is unstressed, it is deleted by apocope. The examples in (42) show that if the stem begins with a sonorant, the vowel *i* is inserted: the initial cluster RC does not occur.

(42)	láʔat	"he hit"	róħos	"it (m) became cheap"
	láʔt-et	"she hit"	róħs-ot	"it (f) became cheap"
	ilʔát-t	"I hit"	irħós-t	"I became cheap"
	ilʔát-na	"we hit"	irħós-na	"we became cheap"
	márad	"he became sick"	néfaħ	"he blew"
	márd-et	"she became sick"	néfħ-et	"she blew"
	imrád-t	"I became sick"	infáħ-t	"I blew"
	imrád-na	"we became sick"	infáħ-na	"we blew"

mášat	"he combed"	néfaʔ	"he spent"
mašt-et	"she combed"	néfʔ-et	"she spent"
imšát-t	"I combed"	infáʔ-t	"I spent"
imšát-na	"we combed"	infáʔ-na	"we spent"

Given only the stress assignment and apocope rules, we predict that /laʔat-na/ → *lʔát-na*: the sonorant plus obstruent sequence is eliminated by the following rule.[6]

(43) ∅ → i / # ___ [+sonor] C

These processes can be seen at work in the imperfective conjugation, which involves a prefix *ni*- "1st person", *ti*- "2nd person" or *yi*- "3rd person" plus a suffix -*u* "plural" for plural subjects. The underlying prefix vowel *i* is seen in the following data.

(44)	ní-msaħ	"I wipe"	tí-msaħ	"you wipe"
	ní-šbaħ	"I resemble"	tí-šbaħ	"you resemble"
	ní-sħaʔ	"I smash"	tí-sħaʔ	"you smash"
	ní-kteb	"I write"	tí-kteb	"you write"
	ní-tlef	"I lose"	tí-tlef	"you lose"

When the first stem vowel is *o*, the prefix vowel harmonizes to *o*.

(45)	nó-bzoʔ	"I spit"	tó-bzoʔ	"you spit"
	nó-krob	"I groan"	tó-krob	"you groan"
	nó-ħlom	"I dream"	tó-ħlom	"you dream"
	nó-ʔtol	"I kill"	tó-ʔtol	"you kill"
	nó-rbot	"I tie"	tó-rbot	"you tie"
	nó-lʔot	"I hit"	tó-lʔot	"you hit"

The stem-initial consonant is important in determining whether there is harmony; if the first consonant is a coronal obstruent, there appears to be no harmony.

(46)	ní-drob	"I wound"	tí-drob	"you wound"
	ní-tlob	"I pray"	tí-tlob	"you pray"
	ní-skot	"I become silent"	tí-skot	"you become silent"
	ní-zloʔ	"I slip"	tí-zloʔ	"you slip"
	ní-šrob	"I drink"	tí-šrob	"you drink"

[6] The reason why this consonant sequence is disallowed is that it involves a "sonority reversal". The universally preferred order of consonants in the syllable onset places obstruents before sonorants.

Examples such as *nó-bzoʔ* show that the coronal obstruent must be immediately after the prefix vowel to have a blocking effect on harmony. The explanation for this apparent failure of harmony is simply that there is a rule fronting *o* when a coronal obstruent follows.

(47) $o \rightarrow [\text{-back}] \ / \ \_\_ \begin{bmatrix} +\text{cor} \\ -\text{son} \end{bmatrix}$

Another process lowers /i/ to *a* before the "guttural" consonants *ʔ* and *ħ*.

(48)	ná-ʔsam	"I divide"	tá-ʔsam	"you divide"
	ná-ʔbad	"I seize"	tá-ʔbad	"you seize"
	ná-ʔbez	"I jump"	tá-ʔbez	"you jump"
	ná-ʔbel	"I agree"	tá-ʔbel	"you agree"
	ná-ħrab	"I flee"	tá-ħrab	"you flee"
	ná-ħraʔ	"I burn"	tá-ħraʔ	"you burn"
	ná-ħdem	"I work"	tá-ħdem	"you work"
	ná-ħleb	"I milk"	tá-ħleb	"you milk"

This motivates the following rule of Guttural Lowering.[7]

(49) $i \rightarrow [+\text{low}] \ / \ \_\_ \begin{matrix} C \\ [+\text{low}] \end{matrix}$

The data in (50) and (51) illustrate another phonological process of the language. In the imperfective form, when the verb stem has a medial obstruent, the prefix vowel is stressed on the surface and the medial stem vowel deletes before the suffix *-u*.

(50)	ní-msaħ	"I wipe"	ní-msħ-u	"we wipe"
	ní-zfen	"I dance"	ní-zfn-u	"we dance"
	nó-bzoʔ	"I spit"	nó-bzʔ-u	"we spit"
	ní-dħol	"I enter"	ní-dħl-u	"we enter"
	ná-ʔsam	"I divide"	ná-ʔsm-u	"we divide"
	ná-ħdem	"I work"	ná-ħdm-u	"we work"

[7] The treatment of the pharyngeal *ħ* as [+low] is uncontroversial, but assigning glottal stop that feature contradicts the standard definition of [+low]. Recent research in feature theory shows that there needs to be a feature including laryngeal glides in a class with low vowels and pharyngeal consonants.

This is as expected: underlying /ni-msaħ-u/ is assigned stress on the first syllable, and the medial unstressed vowel deleted because it is followed by CV. The example [nóbzʔu] from /ni-bzoʔ-u/ shows that harmony must precede apocope, since otherwise apocope would have deleted the stem vowel which triggers harmony.

When the second stem consonant is a sonorant, in the presence of the suffix *-u* the prefix has no stress, and the stem retains its underlying vowel, which is stressed.[8]

(51)	ní-dneb	"I sin"	ni-dínb-u	"we sin"
	ní-tlef	"I lose"	ni-tílf-u	"we lose"
	ní-tlob	"I pray"	ni-tólb-u	"we pray"
	nó-krob	"I groan"	no-kórb-u	"we groan"
	nó-ʔmos	"I kick"	no-ʔóms-u	"we kick"
	ná-ħrab	"I flee"	na-ħárb-u	"we flee"
	ná-ħraʔ	"I burn"	na-ħárʔ-u	"we burn"
	ná-ʔleb	"I overturn"	na-ʔílb-u	"we overturn"
	ná-ħleb	"I milk"	na-ħílb-u	"we milk"

Based solely on stress assignment and apocope, as illustrated in (50), we would predict **nídnbu*, **nótlbu*. This again would result in an inattested consonant cluster in the syllable onset — a sonorant followed by an obstruent — which is avoided by a process of vocalic metathesis whereby *ní-tlif-u* → *ni-tílf-u*.

In some stems which undergo this process of metathesis, the stem vowel alternates between *i* and *a*.

(52)	ní-fraħ	"I rejoice"	ni-fírħ-u	"we rejoice"
	ní-tlaʔ	"I leave"	ni-tílʔ-u	"we leave"
	ní-sraʔ	"I steal"	ni-sírʔ-u	"we steal"

The underlying stem vowel is /i/ in these cases. When no vowel suffix is added, underlying /ni-friħ/ becomes [ní-fraħ] by Guttural Lowering (49). When the suffix *-u* is added, the process of stem-internal metathesis moves underlying /i/ away from the guttural consonant which triggers this lowering process, hence the underlying vowel is directly revealed.

The stems which we have considered previously are of the underlying shape CVCVC. There are also stems with the shape CVVC, illustrated in the perfective aspect in (53).

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[8] Recall that unstressed *i* reduces to [e], so surface [ní-dneb] derives from /ni-dnib/. The underlying high vowel is revealed with the stem vowel is stressed, as in [nidínbu].

(53)	dáar	"he turned"	sáar	"it (masc.) grew ripe"
	dáar-et	"she turned"	sáar-et	"it (fem.) grew ripe"
	dáar-u	"they turned"	sáar-u	"they grew ripe"
	dór-t	"I turned"	sír-t	"I became ripe"
	dór-na	"we turned"	sír-na	"we became ripe"
	dór-tu	"you turned"	sír-tu	"you became ripe"

These stems exhibit a process of vowel shortening where *aa* becomes *o* or *i* (the choice is lexically determined) before a CC cluster.

(54) aa → i,o / __ CC

When the imperfective prefixes *ni-*, *ti-* are added to stems beginning with a long vowel, stress is assigned to that vowel and the prefix vowel is deleted. In the case of the first person prefix /ni/, this results in an initial nC cluster, which is repaired by inserting the vowel *i*.

(55)	in-dúur	"I turn"	in-síir	"I become ripe"
	t-dúur	"you turn"	t-síir	"you become ripe"
	in-súuʔ	"I drive"	in-zíid	"I add"
	t-súuʔ	"you drive"	t-zíid	"you add"

From underlying /ni-duur/, one would expect stress to be assigned to the final syllable because of the long vowel. Since the vowel of the prefix /ni/ would therefore be unstressed and in an open syllable, that vowel should delete, giving *ndúur*. The resulting illicit syllable onset is thus repaired by inserting the vowel *i*.

3.2.2. Apparent Irregularities

A number of verbs seem to be irregular, and yet they are systematic in their irregularity: the irregularity is only in terms of the surface form, which can be made perfectly regular by positing an abstract underlying consonant /ʕ/. One set of examples is seen in the data in (56), where the stem contains a surface long vowel. This long vowel is unexpectedly skipped over by stress assignment, unlike verbs with underlying long vowels such as *in-duur* "I turn" seen in (53).

(56)	ní-sool	"I cough"	ni-sóol-u	"we cough"
	ní-soob	"I lament"	ni-sóob-u	"we lament"
	ní-laab	"I play"	ni-láab-u	"we play"
	ní-baat	"I send"	ni-báat-u	"we send"
	nó-ʔood	"I stay"	no-ʔóod-u	"we stay"
	nó-bood	"I hate"	no-bóod-u	"we hate"

The location of stress and the retention of the prefix vowel in *nó-ʔood* is parallel to the retention of the prefix vowel in other tri-consonantal stems in (44)-(48), such as *ní-msaɧ* "I wipe". If the underlying stem of *ní-sool* had a consonant, i.e. were /sXol/ where X is some consonant yet to be fully identified, the parallelism with *ni-msaɧ* and the divergence from *in-dúur* would be explained. The surface long vowel in *nísool* would derive by a compensatory lengthening side effect coming from the deletion of the consonant X in /ní-sXol/.

Another unexpected property of the stems in (56) is that when the plural suffix *-u* is added, the prefix vowel is stressless and unelided in an open syllable, and the stress shifts to the stem, e.g. *ni-sóol-u* "we cough". Thus contrast *ni-sóol-u* with *ní-msɧ-u* "we wipe" which differ in this respect, and compare *ni-sóol-u* to *ni-šórb-u* "we drink" which are closely parallel. Recall that if the medial stem consonant is a sonorant, expected -CRC-V undergoes metathesis of the stem vowel around the medial consonant, so /ni-šrob-u/ becomes *ni-šórb-u* (creating a closed syllable which attracts stress). If we hypothesize that the stem "cough" is /sXol/, then the change of /ni-sXol-u/ to *ni-sóXl-u* (phonetic *nisóolu*) would make sense, and would further show that X is a sonorant consonant: ʕ qualifies as a sonorant (it involves minimal constriction in the vocal tract).

Another pecularity of these stems is the fact that their long vowels resist shortening before CC.

(57)	sóol	"he coughed"	sóolt	"I coughed"	sóolna	"we coughed"
	sóob	"he lamented"	sóobt	"I lamented"	sóobna	"we lamented"
	ʔáad	"he stayed"	ʔáadt	"I stayed"	ʔáadna	"we stayed"
	báad	"he hated"	báadt	"I hated"	báadna	"we hated"

In contrast to examples in (53) such as *dáar* 'he turned', *dór-t* "I turned" with vowel shortening before CC, these long vowels do not shorten. Continuing with the hypothesis of an abstract underlying consonant in /soXol/, we can explain the preservation of the long vowel in [sóolt] if we assume that this form derives from *sXol-t*, where deletion of X (which we suspect is specifically ʕ) lengthens the vowel, but does so after the rule of vowel shortening has applied.

There is a further anomaly in a subset of stems with the consonant X in the middle of the root: if the initial stem consonant is a sonorant, then epenthetic *i* appears when a consonant-initial (stress-attracting) suffix is added. Compare the examples in (58a) where the first consonant is not a sonorant with those in (58b) where the first consonant is a sonorant.

(58)	a.	ʔáad	"he stayed"	ʔáadt	"I stayed"
		báad	"he hated"	báadt	"I hated"
		sóol	"he coughed"	sóolt	"I coughed"

b.	máad	"he chewed"	imáadt	"I chewed"
	náas	"he dozed"	ináast	"I dozed"
	láaʔ	"he licked"	iláaʔt	"I licked"

The verbs in (58b) behave like those in (42), e.g. *láʔat* "he hit" ~ *ilʔát-t* "I hit" where initial RC undergoes insertion of vowel *i*. The forms in (58b) make sense on the basis of the abstract forms that we are assuming, *máʕad* ~ *mʕádt*, where the latter form undergoes vowel epenthesis and then the consonant ʕ deletes, lengthening the neighboring vowel. Before ʕ is deleted, it forms a cluster with the preceding sonorant, which triggers the rule of epenthesis.

Other mysteries are solved by positing this consonant in underlying forms. In the following examples in the perfective tense, the first stem consonant appears to be a coronal obstruent. We have previously seen that when the stem initial consonant is a coronal obstruent, there is no vowel harmony (or, vowel harmony is undone) as in *ní-tlob* "I pray", so the examples in (59) are exceptional on the surface. In addition, the prefix vowel is long, whereas otherwise is has always been short.

(59)	nóodos	"I dive"	tóodos	"you dive"
	nóoǰob	"I please"	tóoǰob	"you please"
	nóotor	"I stumble"	tóotor	"you stumble"

These forms are unexceptional if we assume that the initial consonant of the stem is not *d, ǰ, t*, but the abstract consonant ʕ, thus /ʕdos/, /ʕǰob/, /ʕtor/: ʕ is not a coronal obstruent, so it does not cause fronting of the prefix vowel.

Other examples, where the stem vowel is not /o/, provide crucial evidence regarding the nature of this abstract consonant. The data in (60) show a lengthened prefix vowel, which argues that the stems underlyingly have the initial abstract consonant that deletes and causes vowel lengthening.

(60)	náalaʔ	"I close"	táalaʔ	"you close"
	náasar	"I squeeze"	táasar	"you squeeze"
	náaraš	"I tickle"	táaraš	"you tickle"

In addition, the quality of the prefix vowel has changed from /i/ to [aa], even though in these examples the consonant which follows on the surface is a coronal. If the abstract consonant is a pharyngeal, then the vowel change is automatically explained by the Guttural Lowering rule.

We have considered stems where the first and second root consonants are the consonant ʕ: now we consider root-final ʕ. The data in (61) shows examples of verbs whose true underlying stems in the perfective are CCV.

(61)	ná-ʔra	"I read"	ná-ʔra-w	"we read"
	ní-mla	"I fill"	ní-mla-w	"we fill"

The plural suffix /u/ becomes [w] after final *a*. Although the second consonant is a sonorant, the metathesis rule does not apply in *náʔraw* because no cluster of consonants containing a sonorant in the middle would result.

Now compare verbs with a medial sonorant where the final consonant is hypothesized /ʕ/. The singular columns do not have any striking irregularities which distinguish them from true CVCV stems.

(62)	ní-sma	"I hear"	ni-síma-w	"we hear"
	ní-zra	"I sow"	ni-zíra-w	"we sow"
	ní-bla	"I swallow"	ni-bíla-w	"we swallow"
	ná-ʔla	"I earn"	na-ʔíla-w	"we earn"

The prefix vowel is unstressed and in an open syllable, which is found only in connection with metathesis: but metathesis is invoked only to avoid clusters of the forms CRC, which would not exist in hypothetical *[níblau]. This can be explained if we assume that the stem ends with /ʕ/ Thus /ni-smiʕ-u/ would be expected to surface as *nisímʕu*, by analogy to /ni-tlob-u/ → [nitólbu] "we ask". The consonant /ʕ/ then induces lowering of the vowel *i*, and ʕ itself is deleted, giving the surface form.

A final set of examples provides additional motivation for assuming underlying ʕ. Participles are formed by giving the stem the shape CCVVC, selecting either *ii* or *uu*. As the data in (63) show, stems ending in the consonant /ʕ/ realise that consonant as [ħ] after long high vowels.

(63)	ʔátel	"he killed"	ʔtíil	"killing"	maʔtúul	"killed"
	ħátaf	"he grabbed"	ħtíif	"grabbing"	maħtúuf	"grabbed"
	kíteb	"he wrote"	ktíib	"writing"	miktúub	"written"
	fétaħ	"he opened"	ftíiħ	"opening"	miftúuħ	"opening"
	téfa	"he threw"	tfíiħ	"throwing"	mitfúuħ	"thrown"
	bála	"he swallowed"	blíiħ	"swallowing"	miblúuħ	"swallowed"
	ʔáta	"he cut"	ʔtíiħ	"cutting"	maʔtúuħ	"cut"
	ʔála	"he earned"	ʔlíiħ	"earning"	maʔlúuħ	"earned"

These data provide evidence bearing on the underlying status of the abstract consonant, since it actually appears on the surface as a voiceless pharyngeal in (63). Although the forms of the participials [ftíiħ] and [tfíiħ] are analogous, we can tell from the inflected forms [fétaħ] "he opened" versus [téfa] "he threw" that the stems must end in different consonants. The most reasonable assumption is that the final consonant in the case of [téfa] is some pharyngeal other than [ħ], which would be [ʕ]. Thus at least for verb stems ending in /ʕ/, the underlying pharyngeal

status of the consonant can be seen directly, even though it is voiceless. Since the abstract consonant can be pinned down rather precisely in this context, we can reason that in all other contexts, the abstract consonant must be /ʕ/ as well.

The crucial difference between these examples of abstractness and cases such as putative /ɨ/ and /ə/ in Hungarian, or deriving [ɔy] from /œ̄/ in English, is that there is strong language-internal evidence for the abstract distinction /u:/ vs. /o:/ in Yawelmani, or for the abstract consonant /ʕ/ in Maltese.

4. Grammar-external evidence for abstractness

Yawelmani and Maltese provide well-motivated abstract analyses, based on patterns of alternation in the grammar. We would still like to find grammar-external that abstract analyses can be psychologically valid reality, analogous to the historical arguments which Kiparsky adduced from the history of Yiddish and Ukranian as supporting a more surface-oriented approach to phonology.

4.1. Abstract analysis and historical change: Tera

One such argument for the psychological reality of abstract analysis comes from Tera. Newman 1972 provides a synchronic and diachronic argument for abstract phonology, where similar surface forms have different underlying forms.

The synchronic argument. The data in (64) illustrate a basic alternation in Tera. Certain nouns ending in [i] in their citation forms lack that vowel in phrase medial contexts.

(64)	na *sedi*	"this is a snake"	na *sed* ɓa	"this is not a snake"
	na *deɓi*	"this is gum"	na *deɓ* ɓa	"this is not gum"

dala wa *wudi*	"Dala pointed"
dala wa *wud* koro	"Dala pointed at the donkey"
dala wa *mbuki*	"Dala threw"
dala wa *mbuk* koro	"Dala threw at the donkey"

Not all words ending in [i] prepausally enagage in this alternation, as the data in (65) demonstrate.

(65)	na *wudi*	"this is milk"	na *wudi* ɓa	"this is not milk"
	a *saɓi*	"this is a stick"	na *saɓi* ɓa	"this is not a stick"

Given a vowel ~ ∅ alternation plus a set of stems which are invariantly *i*-final in (65), we might be led to surmise that the stems in (64) are C-final, and take

an epenthetic vowel [i] phrase-finally. This can be ruled out given the data in (66), where the stem ends in a consonant both phrase-medially and phrase-finally.

(66)	na ruf	"this is a baboon"	na ruf ɓa	"this is not a baboon"
	tin zoɓ	"she is a slob"	tin zoɓ ɓa	"she is not a slob"
	na ɓoŋ	"this is white"	na ɓoŋ ɓa	"this is not white"

A completely surface-oriented account where the underlying form morpheme must be one of the surface variants of the morpheme is untenable: the nouns in (64) have a variant with the vowel [i] but selecting /i/ for the underlying form would fail to distinguish (64) from (65) which always have [i], and the nouns of (64) also have a variant with no final vowel but the nouns in (66) *always* lack a final vowel.

Other roots of the variable-final type give evidence that the problematic stems in (64) uunderlyingly end in schwa. The data in (67) provide monosyllabic words which have the shape *Ci* prepausally and *Cə* phrase medially.

(67)	dala wa ẓi	"Dala received"
	dala wa ẓə sule	"Dala received a shilling"
	dala wa ɗi	"Dala went"
	dala wa ɗə goma	"Dala went to the market"

These words contrast with ones that have invariant [i] in both contexts.

(68)	dala wa ẓi	"Dala paid"
	dala wa ẓi sule	"Dala paid a shilling"
	dala wa vi	"Dala roasted"
	dala wa vi ẓu	"Dala roasted meat"

For the stems in (67), an obvious and nonabstract solution is available: the stems end with /ə/, and that there is a rule turning schwa into [i] prepausally.

(69) ə → i / ___ ##

This rule applies in *dala wa* <u>*ɗi*</u> "Dala went" from *dala wa* <u>*ɗə*</u>, but final schwa is unaffected in *dala wa* <u>*ɗə*</u> *goma* "Dala went to the market". The stems in (68) do not alternate since they end in the vowel /i/. This solution is nonabstract since the underlying form, /ɗə/, is one of the observed surface variants, and as we have emphasised throughout this book, citation forms do not have a special position in terms of the logic of discovering an underlying form.

There are other stems with final [i] prepausally and [ə] phrase medially.

(70)	na pərsi	"this is a horse"
	na pərsə ɓa	"this is not a horse"

dala wa kədi	"Dala pulled"
dala wa kədə koro	"Dala pulled a donkey"

These stems all either have the shape [CVCCə] phrase-medially, or else [CVZə] where Z is a voiced consonant.

This gives the following groups of stems with an underlying final schwa.

(71)

Stem shape	*medial*	*prepausal*
Cə	Cə	Ci
CVCCə	CVCCə	CVCCi
CVZə	CVZə	CVZi
CVCə	CVC	CVCi

For most of these stems, postulating underlying schwa is quite concrete, since schwa actually surfaces in phrase-medial context. However, in polysyllabic stems such as *deɓi* ~ *deɓ* with a single voiceless consonant before the final schwa, the analysis is abstract because schwa is never phonetically manifested. The decision that the vowel in question is schwa is based on analogy with a known behavior of schwa: it becomes [i] prepausally.

Our analysis requires a rule delete word-final phrase-medial schwa providing the stem is polysyllabic and ends only in a single voiceless consonant.

(72) $$\text{ə} \rightarrow \varnothing \;/\; \text{V} \quad \underset{[\text{-voice}]}{\text{C}} \quad \underline{\quad} \;\; \#\ldots$$

More evidence supports abstract schwa in certain words. The examples in (73a) show that when a vowel -*a* marking definite nouns is suffixed to a stem such as /pərsə/ which ends in schwa, schwa deletes, whereas underlying /i/ is not deleted. The data in (73b) show the same thing with the imperative suffix /u/.

(73)

a.	pərsi ← /pərsə/	"horse"	pərs-a	"the horse"
	wuɗi	"milk"	wuɗi-a	"the milk"
b.	vi	"to roast"	vi-u	"roast!"
	ɗi ← /ɗə/	"to go"	ɗ-u	"go!"
	kədi ← /kədə/	"to pull"	kəd-u	"pull!"
	mbuki ← /mbukə/	"to throw"	mbuk-u	"throw!"

This motivates a rule of prevocalic schwa deletion, which provides another diagnostic that differentiates schwa from /i/.

(74) $$\text{ə} \rightarrow \varnothing \;/\; \underline{\quad}\ \text{V}$$

Although "throw" only has the surface variants [mbuki] ~ [mbuk], it behaves exactly like stems such as /kədə/ where schwa is phonetically realized, and acts unlike /vi/, in losing its final vowel before another vowel.

Finally, there is an allomorphic variation in the form of the adjective suffix *-kandi*, which shows up as *-kandi* when the stem ends in a vowel (*saɓir taɗa-kandi* "heavy stick") and as *-ndi* when the stem ends in a consonant (*saɓir teɓer-ndi* "straight stick"). The stem "long" ends in abstract schwa, since it alternates between final [i] (*saɓira kəri* "the stick is long") and medial ∅ (*saɓira kər ɓa* "the stick is not long"). Furthermore, the stem selects the post-vocalic variant of the adjective suffix (*saɓir kər-kandi* "long stick"), even though on the surface the stem ends with a consonant and not a vowel. This anomaly is explained by the hypothesis that the stem does in fact end in a vowel, namely schwa.

The diachronic argument. Thus multiple lines of argument establish the presence of an abstract vowel schwa in a number of words in the synchronic grammar of Tera. A recent sound change in Tera provides a grammar-external test of the validity of the abstract hypotheses. In one particular dialect of Tera, spoken in the town of Zambuk, a phonological rule was added to the grammar which palatalized *t*, *d* and *ɗ* to *c, j* and *j'* before i. In comparison, the dialect of Tera spoken in Wuyo is representative of the rest of Tera, in retaining the original alveolars. Thus we find Wuyo *da*, Zambuk *da* "one" with no palatalization before *a*, but Wuyo *di*, Zambuk *ji* "to get up" where *d* palatalizes in the Zambuk dialect. There are synchronic alternations which further motivate this palatalization process in the contemporary grammar of the Zambuk dialect, so where the Wuyo dialect has *xat-a* "my brother", *xat-in* "his brother", the Zambuk dialect has *xat-a*, *xac-in*. In Wuyo one finds *wuɗî* "milk" and in Zambuk one finds *wuj'i*, deriving from /wuɗi/ — that the final vowel is /i/ and not /ə/ is shown by the phrase medial form *wuɗî*.

While palatalization is active in the Zambuk dialect, it does not affect all surface sequences of alveolar plus [i], in particular it does not affect [i] which derives from schwa. In the Wuyo dialect "to pull" is *kədi* before pause, *kədə* medially (cf. *dala wa kədə koro* 'Dala pulled a donkey'), and therefore we know that the stem is /kədə/. In the Zambuk dialect, the medial form is also *kədə*, showing that the stem does end in schwa in that dialect, and the prepausal form is *kədi*. Thus palatalization does not apply to the output of final schwa-fronting: the failure of palatalization to apply to this derived [di] sequence provides another diagnostic of the distinction between /i/ and [i] derived from /ə/.

Further confirming our hypothesis about abstract schwa, the stem /wuɗə/ "to point" which appears in the Wuyo dialect as *wuɗî* prepausally and as *wuɗ* medially (*dala wa wuɗ koro* "Dala pointed at a donkey") appears as *wuɗî* in the Zambuk dialect, without palatalization, as is regularly the case with the vowel [i] derived from /ə/. The fact that the innovative sound change of palatalization found in the Zambuk dialect is sensitive to the sometimes abstract distinction between underlying versus derived schwas, especially in cases such as /wuɗə/ where the pos-

tulated schwa is truly abstract since it never appears on the surface, gives important support to the claim that abstract underlying forms can be psychologically real.

4.2. Abstract reanalysis in Kimatuumbi NC sequences

Other historical evidence for the reality of abstract phonology comes from a historical reanalysis of postnasal consonants in the Bantu language Kimatuumbi. Nouns in Bantu languages are composed of a prefix plus stem, and the prefix changes between singular and plural. For example the proto-Bantu word *mu-ntu* "person" contains the Class 1 prefix *mu-* marking certain singular nouns, and the plural *ba-ntu* "people" contains the Class 2 prefix *ba-*. Different nouns take different noun-class prefixes (following the tradition of historical lingusitics, reconstructed forms are marked with an asterisk).

(75)	*PB singular*	*class*	*PB plural*	*class*	*gloss*
	*mʊ-ntʊ	1	*ba-ntʊ	2	person
	*mʊ-gʊnda	3	*mɪ-gʊnda	4	field
	*li-tako	5	*ma-tako	6	buttock
	*m-paka	9	*dim-paka	10	cat
	*lʊ-badu	11	*dim-badu	10	rib

A post-nasal voicing rule was added in the Proto-Rufiji-Ruvuma subgroup of Bantu (a subgroup which includes Kimatuumbi), so that original **mpaka* "cat" came to be pronounced *mbaka* in this subgroup.

(76)	*Proto-Bantu*	*Kimatuumbi*	
	*mpaka	mbaka	"cat"
	*ŋkaŋga	ŋgaaŋga	"guinea fowl"
	*ntembo	ndeembo	"elephant"
	*mʊntʊ	muundu	"person"
	*mpembe	mbeembe	"horn"
	*ŋkʊŋgʊnɪ	ŋguuŋguni	"bedbug"
cf.	*mbabada	mbabala	"bushbuck"
	*mbʊdị	mbwi	"goat"
	*mbʊa	mbwa	"dog"

Another inconsequential change affecting this subgroup of languages is that the class 10 prefix, originally **din-*, lost *di*, so the class 10 prefix became completely homophonous with the class 9 prefix.

In the Nkongo dialect of Kimatuumbi, there was a change in the morphological system so that nouns which were originally assigned to classes 9-10 now form their plurals in class 6, with the prefix *ma-*. Earlier **ŋaambo* "snake ~ snakes" now has the forms *ŋáambo* "snake" / *ma-ŋáambo* "snakes".

Given a surface form [mbwa] "dog" (from proto-Bantu *m-bʊa), originally in noun class 9-10, the phonetically concrete analysis is that the underlying form in proto-Rufiji is /m-bwa/. It is always pronounced as [mbwa], and the root is always preceded by a nasal prefix since both the singular and plural prefixes end in a nasal. No alternations in the phonetic realization of the initial consonant would give reason to think that phonetic [b] derives from underlying /b/. By the same reasoning, we predict that the underlying form of earlier *mpaka* "cat" is reanalysed as /b/, once the word came to be pronounced as *mbaka* in all contexts.

The restructuring of the morphological system on Nkongo Kimatuumbi whereby the original class pairing 9-10 is reanalyzed as 9-6 allows us to test this prediction, since nouns with their singulars in class 9 no longer have a nasal final prefix in all form: the plural has the prefix *ma-*. As the following data show, the concrete approach is wrong.

(77)

Proto-Bantu	*Kimatuumbi singular*	*Original plural*	*Innovative plural*	
*m-pembe	m-beembe	m-beembe	ma-peembe	"horn"
*ŋ-kʊkʊ	ŋ-guku	ŋ-gʊkʊ	ma-kuku	"chicken"
*m-bʊa	m-bwa	m-bwa	ma-pwa	"dog"
*m-babada	m-babala	m-babala	ma-pabala	"bushbuck"
*m-bʊdi	m-bwi	m-bwi	ma-pwi	"goat"
*m-baŋgo	m-baaŋgo	m-baaŋgo	ma-paaŋgo	"warthog"
*m-bʊtʊka	m-bʊtʊka	m-bʊtʊka	ma-pʊtʊka	"antelope"

We see that while the distinction between /mp/ and /mb/ was neutralized, it was neutralized in favor of a phonetically more abstract consonant /p/ rather than the concrete consonant /b/.

This reanalysis did not affect all nouns which had a singular or plural in class 9-10; it affected only nouns which originally had both their singulars and plurals in this class, i.e. only those nouns lacking alternation. Nouns with a singular in class 11 and a plural in class 10 preserve the original voicing of the consonant.

(78)

PB	*Kimatuumbi singular*	*Kimatuumbi plural*	
*m-badu	lu-bau	m-bau	"rib"
*n-godi	lu-goi	ŋ-goi	"rope"
*n-dɪmi	lu-lɪmi	n-dɪmi	"tongue"
*ŋ-kʊŋgʊnɪ	lu-kuuŋguni	ŋ-guuŋguni	"bedbug"
*n-tondʊa	lu-toondwa	n-doondwa	"star"

A word such as "rib" always had a morphological variant of the word which transparently revealed the underlying consonant, so the contrast between /n-toondwa/

→ [ndoondwa] and /n-goi/ → [ŋgoi] was made obvious by the singulars [lu-toondwa] and [lu-goi].

While it is totally expected that there should be a neutralization of **mp* and **mb* in words like *mbaka, mbwa*, since there would have been no evidence to support a distinction between surface [mb] deriving from /mb/ versus [mb] deriving from /mp/, surprisingly from the viewpoint of concrete phonology, the direction of neutralization where [mb] is reanalysed as /mp/ is unexpected. One explanation for this surprising reanalysis regards the question of markedness of different consonants. Given a choice between underlying /m+b/ and /m+p/, where either choice would independently result in [mb], one can make a phonetically conservative choice and assume /m+b/, or make a choice which selects a less marked consonant, i.e. /m+p/. In this case, it is evident that the less marked choice is selected, just in case the choice of consonants is empirically arbitrary.

Such examples illustrating phonetically concrete versus abstract reanalyses motivated by considerations such as markedness are not well enough studied that we can explain why language change works one way in some cases, and another way in other cases. In the case of Yiddish *avek* from historically prior *aveg*, there would be no advantage at all to assuming underlying /aveg/, from the perspective of markedness or phonetic conservatism. In the case of Ukranian *meža* from *meǰa*, a choice was made in favor of the concrete form /meža/, which may indicate that the alternative of /meǰa/ does not constitute a sufficient improvement in markedness to warrant selecting an abstract underlying form. It remains possible that such choices are random: this is an open area of research.

4.3. Language games and Bedouin Arabic

Language games can also provide evidence for the mental reality of underlying representations. Their relevance is that language game modifications are not always performed on the surface form, so by modifying the phonetic environment in which segments appear, game may cause rules to apply when they would not normally (providing evidence for the reality of the phonological process), or prevent a rule from applying when it normally would (revealing the abstract underlying form). An example of such evidence comes from Bedouin Arabic spoken in Saudi Arabia, discussed by Al-Mozainy 1984. A number of verbs have the underlying form /CaCaC/, but this analysis is abstract in that, for these verbs, the first vowel sequence is never found on the surface, and surfaces as [CiCaC].

4.3.1. REGULAR LANGUAGE PHONOLOGY

We begin by motivating aspects of the phonology of the language, especially underlying representations, using regular language data. Verb stems may have different underlying vowels, but the passive is formed by systematically re-

placing all underlying vowels with /i/. Underlying /i/ deletes in an open syllable, as shown by the following data.

(79)	*3sg Masc*	*3sg Fem*	*1sg*	
	ħzim	ħizm-at	ħzim-t	"be tied"
	ħfir	ħifr-at	ħfir-t	"be dug"
	šrib	širb-at	šrib-t	"be drunk"
	ʕzim	ʕizm-at	ʕzim-t	"be invited"
	lbis	libs-at	lbis-t	"be worn"

Taking underlying /ħizim/ and /ħizim-t/ as examples, the vowel /i/ in the first syllable is in an open syllable, so the rule of high-vowel deletion applies, giving [ħzim] and [ħzimt]. In the case of /ħizim-at/, both vowels *i* are in an open syllable: the second *i* deletes, which makes the first syllable closed, and therefore the first vowel does not delete, resulting in [ħizmat]. The following rule of high-vowel deletion is thus motivated by these data.

(80) $i \rightarrow \varnothing$ / __ CV

Now we consider another class of nonpassive verbs, where the underlying stem shape is CaCiC. In these stems, the second vowel shows up as *i* when there is no vowel after the stem. The first vowel of the stem alternates between [i] and [a], surfacing as [i] when the second vowel appears as [i], otherwise surfacing as [a]. Examples of verbs with this vocalic pattern are seen in (81).

(81)	*3sg Masc*	*3sg Fem*	*1sg*	
	simiʕ	samʕ-at	simiʕ-t	"hear"
	libis	labs-at	libis-t	"wear"
	širib	šarb-at	širib-t	"drink"
	yibis	yabs-at	yibis-t	"become dry"
	silim	salm-at	silim-t	"save"
	ħilim	ħalm-at	ħilim-t	"dream"
	fixir	faxr-at	fixir-t	"be proud"

In underlying /samiʕ-at/, the vowel /i/ is in an open syllable so it delete, giving [samʕat]. In /samiʕ/ and /samiʕ-t/, final /i/ does not delete since it is not in an open syllable, and /a/ assimilates to [i] before [i], by the following harmony rule.

(82) $a \rightarrow i$ / __ C i

Note that this creates a surface [i] in an open syllable which does not undergo deletion.

Now we turn to stems with the underlying shape /CaCaC/. In a number of such verbs this representation is uncontroversial since that it how it surfaces.

(83)	*3sg Masc*	*3sg Fem*	*1sg*	
	gaʕad	gʕad-at	gaʕad-t	"sit"
	waʕad	wʕad-at	waʕad-t	"promise"
	ṭaʕan[9]	ṭʕan-at	ṭaʕan-t	"stab"
	saħab	sħab-at	saħab-t	"pull"
	ṭaħan	ṭħan-at	ṭaħan-t	"grind"
	daxal	dxal-at	daxal-t	"enter"
	naxal	nxal-at	naxal-t	"sift"

Examples such as [gʕadat] from /gaʕad-at/ illustrate the application of another rule, one deleting /a/ when followed by CVCV.

(84) a → ∅ / __ CVCV

An important fact about the stems in (83) is that the second consonant is a guttural (*x, γ, ħ, h, ʔ* or ʕ). There is a dissimilative process in the language turning /a/ into [i] in an open syllable if the next vowel is /a/, providing that the vowel is neither preceded nor followed by a guttural consonant. In the above examples, the consonant in the middle of the stem is a guttural, so neither the first nor the second vowels can undergo the dissimilative raising rule. Now consider the data in (85), where the first consonant is a guttural but the second is not.

(85)	*3sg Masc*	*3sg Fem*	*1sg*	
	ʕazam	ʕzim-at	ʕazam-t	"invite"
	ħazam	ħzim-at	ħazam-t	"tie"
	hakam	hkim-at	hakam-t	"rule"

Here the first vowel of the stem cannot become [i] because of the preceding consonant, but the second vowel does dissimilate to [i] when followed by /a/, and thus /ʕazam-at/ becomes [ʕzimat] (with deletion of the first vowel by (84)). This rule is separate from the harmony rule that turns /a/ into [i] before [i], because harmony applies irrespective of the flanking consonants, cf. [ħilim] "he dreamt".[10]

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[9] Following Semitic transcription practices, pharyngealised coronals are indicated with a dot underneat the consonant.

[10] This verbal restriction on the consonant next to the target vowel goes beyond what is allowed in the version of the formal theory presented here. How such conditions are to be incorporated into an analysis has been the subject of theoretical debate.

(86) a → i / ___C V (/a/ is nor adjecent to a guttural consonant)

In [ʕazam] and [ʕazamt], there is no dissimilation because the first consonant is guttural, which prevents the following /a/ from undergoing dissimilation.

Examples in (87) show the same restriction on dissimilation of the second vowel /a/, which does not become [i] when the last consonant is a guttural.

(87)	*3sg Masc*	*3sg Fem*	*1sg*	
	difaʕ	dfaʕ-at	difaʕ-t	"push"
	ṛikaʕ	ṛkaʕ-at	ṛikaʕ-t	"bend"
	xadaʕ	xdaʕ-at	xadaʕ-t	"cheat"

Another consonantal property inhibiting dissimilation is a coronal sonorant. In this case, if the two vowels are separated by any of /n, r, l/, there is no dissimilation. In the examples of (88), the first vowel is prevented from dissimilating because the vowel is preceded by a guttural. The second vowel is prevented from dissimilating because it is separated from /a/ by a coronal sonorant. Therefore, both underlying stem vowels remain unchanged.

(88)	*3sg Masc*	*3sg Fem*	*1sg*	
	ħafar	ħfar-at	ħafar-t	"dig"
	ħamal	ħmal-at	ħamal-t	"carry"
	γasal	γsal-at	γasal-t	"wash"

In the examples of (89), the first vowel is followed by a consonant other than a coronal sonorant, and is neither preceded nor followed by a guttural. Therefore, the first vowel dissimilates to [i]. The second vowel is followed by a coronal sonorant, so there is no dissimilation in the second syllable.

(89)	*3sg Masc*	*3sg Fem*	*1sg*	
	nizal	nzal-at	nizal-t	"get down"
	sikan	skan-at	sikan-t	"occupy"
	kisar	ksar-at	kisar-t	"break"
	difan	dfan-at	difan-t	"bury"
	nital	ntal-at	nital-t	"steal"
	šitar	štar-at	šitar-t	"divide"

In (90) we find verbs with a coronal sonorant as the second consonant. The second vowel /a/ dissimilates before *a*, since the intervening consonant is neither guttural not a coronal sonorant. The preceding coronal sonorant has no effect on dissimilation, since unlike the effect of gutturals, coronal sonorants only have an effect if they stand after the target vowel.

(90)	*3sg Masc*	*3sg Fem*	*1sg*	
	jalas	jlis-at	jalas-t	
	gaṛaṣ	gṛiṣ-at	gaṛaṣ-t	"sting"
	gaṛaṭ	gṛiṭ-at	gaṛaṭ-t	"throw"
	sarag	srig-at	sarag-t	"steal"
	balas	blis-at	balas-t	"denounce"
	šanag	šnig-at	šanag-t	"hang"
	daras	dris-at	daras-t	"study"

Finally, verbs with no gutturals or coronal sonorants are given in (91).

(91)	3sg Masc	3sg Fem	1sg	
	kitab	ktib-at	kitab-t	"write"
	misak	msik-at	misak-t	"catch"
	sikat	skit-at	sikat-t	"stop talking"
	nitaf	ntif-at	nitaf-t	"pluck"
	gisam	gsim-at	gisam-t	"divide"
	giðab	gðib-at	giðab-t	"catch"
	nikas	nkis-at	nikas-t	"retain"

By the deletion rule (84), underlying /katabat/ becomes *ktabat*, which becomes [ktibat] by dissimilation. In /katab-t/, since the first vowel is not followed by CVCV it cannot elide, and it dissimilates to [i] before [a] in the second syllable.

The claim that the second syllable of verbs like [kitab] contains underlying /a/ is mildly abstract, insofar as it shows up with [a] as long as it is not open. The claim that the first syllable contains /a/, on the other hand, is abstract since there is no context in this verb where the underlying /a/ appears as such in these verbs, and instead the vowel only appears as [i]. However, we know that the initial vowel cannot be /i/, since if it were, that vowel would delete in an open syllable — contrast active [kitab] and [kitabt] from /katab/ and /katab-t/, with the passives [ktib] and [ktibt] from /kitib/ and /kitib-t/.

The occurrence of non-deleting [i] in an open syllable is entirely predictable. It appears when neither the first nor second stem consonants are gutturals, and when the second stem consonant is not a coronal sonorant. This non-deleting [a] is thus in complementary distribution with surface [a] (which non-abstractly derives from underlying /a/), which only appears when one of the first two consonants is a guttural or the second consonant is a coronal sonorant.

Hence there is strong language-internal motivation for claiming that the initial vowel of stems such as [kitab] is underlyingly /a/, and is subject to dissimilation to [i] or deletion. This analysis is abstract in that the vowel of these roots does not appear as [a]. However, by analogy to stems such as *jalas* or *ḥaṛar* which do manifest the vowel [a] phonetically, we can suspect that the first vowel of all non-passive verbs is in fact underlying /a/.

4.3.2. Language Game Evidence

There is a language game used by speakers of Arabic which provides independent evidence for the mental reality of these rules and underlying representations. The rule for the language game is very simple: permute the order of consonants within the root. Now let us consider the various phonetic results of permutation on the the verb forms *ħazam* "he tied" and *ħzim-at* "she tied".

(92)	"he tied"	"she tied"	
	ħamaz	ħmizat	~
	zaħam	zħamat	~
	zimaħ	zmaħat	

In the unpermuted form *ħazam*, the first vowel does not dissimilate because of the preceding guttural; in unpermuted *ħzimat* the second stem vowel dissimilates because it is neither preceded nor followed by a gutural, and is not followed by a coronal sonorant. In the permuted forms *ħamaz* and *ħmizat*, where the second and third consonants have exchanged place, the vocalic pattern remains the same because the transposition has not crucially changed the consonantal environment.

Now consider the forms *zimaħ* ~ *zmaħat*. This pattern of transposition has two effects on the vowel pattern. First, because the first consonant is now not a guttural, the dissimilation rule can apply in the first syllable, demonstrating the reality of the dissimilation rule. Second, because the final consonant is now a guttural, the dissimilation rule cannot apply in the second syllable, demonstrating the reality of the blocking condition on dissimilation. Finally, in the case of *zaħam* ~ *zħamat*, because the medial consonant is a guttural, neither vowel can dissimilate.

A crucial example, in terms of testing the validity of the proposed /CaCaC/ underlying form for surface [CiCaC] stems, is a stem such as /dafaʕ/ "push", which surfaces as [difaʕ]. Such a supposed underlying representation is abstract, since the vowel of the first syllable always surfaces as [i] or ∅, cf. *difaʕ* "he pushed", *dfaʕat* "she pushed", never as *a*. This stem contains a final pharyngeal consonant, and therefore movement of that consonant to first or second position will put the first vowel in contact with a pharyngeal: this should then block dissimilation, and will directly reveal the hypothesized underlying vowel.

(93)	"he pushed"	"she pushed"	
	fidaʕ	fdaʕat	~
	daʕaf	dʕafat	~
	ʕadaf	ʕdifat	~
	ʕafad	ʕfidat	

The fact that this vowel actually surfaces as [a] under the circumstances predicted by the abstract hypothesis gives strong support to the claim for an abstract representation of such stems as having the vowel pattern /CaCaC/.

5. How Abstract *is* Phonology?

We may now summarise our investigation into the question of abstract representations in phonology. On the one hand we have argued for abstract analyses of Kimatuumbu, Yawelmani, Maltese and other languages; but we have argued against abstract analyses of English. The reason for this apparent inconsistent view of abstractness is that abstractness per se is not the issue; the right question to be focusing on is what motivates an analysis. Thus we conclude that the formal theory of grammar does not impose any constraints on the relation between underlying and surface forms, though the theory does (at least by assumption) state what kinds of elements can exist in underlying representations, specifically, phonetically interpretable combinations of features, i.e. segments.

This does not mean that highly abstract underlying representations can be gratuitously assumed. Underlying representations need to be motivated, because they must be acquired by children learning the language, and the best assumption to make is that in lieu of evidence to the contrary, underlying and surface forms should be identical. The question that needs further investigation is, what constitutes valid 'evidence to the contrary'? Actual phonological alternations in the shape of a morpheme provide very powerful evidence for abstractness. It remains an open question whether other considerations are also valid in constructing an underlying form.

Although we have focused on the relation between underlying and surface forms, the more important question which this raises is, what counts as valid evidence for testing a phonological theory. It has proven extremely difficult to resolve questions about the psychological reality of theorized linguistic constructs. Two approaches, both valid, have been taken. One is the "domain-internal" approach, where formal constraints are proposed to the effect that (for example) underlying forms should be a subpart of an actually pronounced word in the language, or underlying forms should only contain segments are actually pronounced in the language. We cannot show that these claims are literally "wrong": what we can do is show that if you take such a position, you will be unable to capture important generalizations about the phonologies of Maltese and Yawelmani, for example.

The other approach, the "domain-external" approach, seeks evidence from outside the domain of synchronic phonological grammars themselves, in an attempt to find independent evidence that answers the question of what is actually in the mind of the speaker. Any number of such approaches can be imagined — neurosurgery, psycholinguistic testing, language games, historical change, the study of language acquisition, and so on. Such evidence is extremely hard to find in the first place: virtually all relevant experimental work is conducted on a tiny handful of

commonly spoken languages, which typically do not have internally well-motivated abstractness. Additionally, the experimental methodology must be critically evaluated, which is usually very difficult to do outside of one's own discipline. Finally the evidence must be interpreted against a general theory of e.g. child developmental psychology. The question of how to empirically validate theory-internal hypotheses remains very much an open question in phonology, as it is in all scientific domains.

Exercises

1. Slovak

The focus of this problem is the underlying representation of diphthongs. Discuss the underlying status of diphthongs in Slovak, based on these data.

A. There is a process of lengthening which takes place in certain morphological contexts, including the genitive plural and the diminutive.

nom. sg	*gen. pl.*	
lip	li:p	'linden tree'
muxa	mu:x	'fly'
lopata	lopa:t	'shovel'
srna	sr̩:n	'deer'
žena	žien	'woman'
kazeta	kaziet	'box'
hora	huor	'forest'
sirota	siruot	'orphan'
pæta	piat	'heel'
mæta	miat	'mint'
kopito	kopi:t	'hoof'
bruxo	bru:x	'belly'
blato	bla:t	'mud'
salto	sa:lt	'somersault'
embargo	emba:rg	'embargo'
yabl̩ko	yabl̩:k	'apple'
koleso	kolies	'wheel'
lono	luon	'lap'
hovædo	hoviad	'beast'
vla:da	vla:d	'government'
blu:za	blu:z	'blouse'
dla:to	dla:t	'chisel'
vi:no	vi:n	'vine'
čiara	čiar	'line'
hniezdo	hniezd	'nest'

noun	*diminutive*	
hrad	hra:dok	‘castle’
list	li:stok	‘leaf’
xlp	xl:pok	hair’
kvet	kvietok	flower’
hovædo	hoviadok	‘beast’

B. There is also a shortening rule that applies in certain morphological contexts, including the imperfective of verbs and the comparative of adjectives.

perfective	*imperfective*	
odli:sit^{y}	odlisovat^{y}	‘to distinguish’
ku:pit^{y}	kupovat^{y}	‘to buy’
ohla:sit^{y}	ohlasovat^{y}	‘to announce’
predl:žit^{y}	predlzvat^{y}	‘to extend’
oblietat^{y}	obletovat^{y}	‘to fly around’
uviazat^{y}	uvæzovat^{y}	‘to bind’

adjective	*comparative*	
bli:ski	blišsi:	‘near’
u:ski	ušši:	‘narrow’
kra:tki	kratši:	‘short’
bieli	belši:	‘white’
rietki	retši:	‘rare’

C. There is an alternation in the form of case suffixes which is governed by properties of the stem which precedes

n.s	*g.s*	*n.p*	*d.p*	*l.p*	
mesto	mesta	mesta:	mesta:m	mesta:x	‘town’
blato	blata	blata:	blata:m	blata:x	‘mud’
hovædo	hovæda	hovæda:	hovæda:m	hovæda:x	‘town’
pi:smeno	pi:smena	pi:smena:	pi:smena:m	pi:smena:x	‘letter’
za:meno	za:mena	za:mena:	za:mena:m	za:mena:x	‘pronoun’
dla:to	dla:ta	dla:ta	dla:tam	dla:tax	‘town’
vi:no	vi:na	vi:na	vi:nam	vi:nax	‘wine’
hniezdo	hniezda	hniezda	hniezdam	hniezdax	‘nest’

n.s	*g.s*	
za:hrada	za:hrad	'garden'
ni:žina	ni:žin	'hollow'
za:toka	za:tok	'inlet'
pi:smeno	pi:smen	'letter'
za:meno	za:men	'pronoun'
liečivo	liečiv	'drug'

D. Some stems underlyingly end with consonant clusters, and undergo a process of vowel epenthesis that eliminates certain kinds of consonant clusters.

n.s	*g.s*		
ikra	ikier	'roe'	(cf. also ikernati: 'abounding in roe')
ihla	ihiel	'needle'	
dogma	dogiem	'dogma'	
sosna	sosien	'pine tree'	
bedro	bedier	'hip'	
radlo	radiel	'plow'	
hradba	hradieb	'rampart'	
doska	dosiek	'board'	
kri:dlo	kri:del	'wing'	
či:slo	či:sel	'number'	
pa:smo	pa:sem	'zone'	
vla:kno	vla:ken	'fiber'	
pla:tno	pla:ten	'linen'	

Advanced Topics and Readings

In addition to Chomsky & Halle 1968, which established a characteristic mode of reasoning valuing formal simplicity of grammars as the highest criterion for evaluating grammars and claims about grammars, a number of phonological works in that era would freely invoke abstract distinctions to solve what would currently be considered to be small problems, ones not warranting those assumptions about underlying forms. Thus Zwicky 1965 proposed that retroflex stops of Sanskrit in root-final position be derived from /lt/, /ld/, /lth/, /ldh/, in order to effect a formal simplification of the grammar. Harris 1969 proposes that there is an underlying tense / lax contrast in Spanish mid vowels although all vowels are tense on the surface, in order to distinguish those vowels which diphthongize when stressed (*contár* "to count", *cuénto* "I count") from those which do not (*montár* "to mount", *mónto* "I mount"). Lightner 1972 gives a very abstract account of Russian phonology, particularly driven by the principle of reducing underlying segments, so that the non-alternating nouns *šum* "noise" is derives from /xeumax/.

A number of works including Crothers 1973, Hudson 1974, Vennemann 1974 and Hooper 1976 reacted to such highly abstract analyses, and the latter three scholars proposed an alternative framework, the theory of Natural Generative Phonology, which prohibited such abstract analyses by imposing conditions on underlying forms themselves (e.g. an underlying form must be one of the observed surface variants), and which prohibited the rule ordering necessary for an abstract analysis to be implementable. Even practicioners staying within the theoretical assumptions of standard generative phonology of the time called into question the highly abstract analysis of English proposed in SPE: cf. Hoard 1972, Goyvaerts & Pullum 1975, Lightner 1976, and of course Kiparsky 1968 which provided the whole impetus for this line of questioning.

Other cases of reasonably-well motivated absolute neutralization beyond the celebrated cases of Yawelmani and Maltese include Nupe (proposed in Hyman 1970, 1973; argued against in Harms 1973); various Uralic and Altaic languages discussed in Vago 1973, especially in Manchu (also argued for in Odden 1978); Piggott 1980, which argues for abstract short /e/ in Odawa in order to distinguish instances of surface [i] which trigger palatalization and fail to trigger vowel coalescence from other instances of surface [i] which fails to trigger palatalization and do trigger vowel coalescence. Vago 1973 also shows that a Kiparsky-style rule-exception analysis of Hungarian does not work, since that analysis requires alternating suffix vowels to all be [+back] whereas in fact there is a lexical contrast between front and back vowels in harmonically alternating suffixes.

The topic of the psychological reality of various phonological entities is discussed in a number of places. Sapir 1933 is particularly important in providing some of the the first and most widely known arguments for a particular analysis (of Southern Paiute and Nootka) based on the behavior of speakers of unwritten languages attempting to render their languages in written form for the first time. Similar evidence from outside the standard corpus of forms generated by a grammar has involved poetry (Zeps 1963, Kiparsky 1968b, Malone 1982, 1988, Chen 1984), language games (Chao 1934, Sherzer 1970, Hombert 1973, Campbell 1980, McCarthy 1985, Bagemihl 1988, Bao 1990, Piñeros 1998), patterns of adaptations in borrowed words (Hyman 1973, Lovins 1975, Silverman 1992, Paradis 1996, Paradis & Prunet 2000), speech errors (Fromkin 1971, Stemberger 1985, Stemberger & Stoel-Gammon 1991), and historical change along the lines of the Yiddish and Tera evidence discussed above (Skousen 1975, Kiparsky 1982).

11

Nonlinear Representations

This final chapter introduces an alternative model, the nonlinear theory, of how sounds are represented. The purpose of this chapter is to show how troublesome facts can lead to a reconceptualization of a domain which seemed to be understood, leading to an even better understanding of the nature of language sounds. This will also help you to understand how and why theories change.

The theoretical model which we have been assuming — known as the lib-near theory of representation — was generally accepted and proved to be quite successful in explaining a number of facts about sound systems. A defining characteristic of the theory is the view of segments as being matrices of feature values where every segment has a specification for each of the two dozen distinctive features. There was, however, one phonological realm which the theory had largely ignored, and that was tone.

1. The Autosegmental theory of tone: the beginnings of a change

There were a few proposals regarding features for tone, but they did not reach the degree of acceptance that those for other features had reached. One of the primary problems that impeded the development of a set of features for tone was how to represent contour tones such as rising and falling.

1.1. The problem of contours

One possibility is that contour tones are simply H or L tones with a positive specification for a feature "contour". We could take the pitch at the beginning of a vowel as representing the "basic" tone value, and if the pitch changes from that point (either up or down), then the vowel is [+contour]. This gives us the following representations of H, L, R (rising) and F (falling) tones.

(1) H = [+H,-contour] R = [-H,+contour]
L = [-H,-countour] F = [+H,+contour]

Such a theory would ultimately be inadequate since it ignores tone levels (Mid, Superlow, Superhigh), but we can pursue this theory to see what progress can be made. Perhaps if this theory works, it can be modified to account for other tone levels.

An essential test of any theory of features is how well it accounts for phonological processes. This theory of tone representations makes predictions, for example it predicts that R and F will be a natural class because they are [+countour], and it predicts that L and R are a natural class because they are [-H]. As it happens, some relevant typological work had been done on natural tone rules, most noteably Hyman & Schuh 1974. Such research has shown that the following are fairly common tonal processes.

(2) a. H → R / {L,F} ___ b. L → F /{H,R} ___
c. H → F / ___ {L,R} d. L → R / ___ {H,F}

The problem is that the "[±contour]" theory does not provide any natural way to express all of these processes. The last two processes can be formulated:

(3) c. [+H] → [+contour] / ___ [-H]
d. [-H] → [+contour] / ___ [+H]

However, the first two processes cannot be formalized, since {L,F} or {H,R} are not a definable class using this theory.

This theory also predicts the following rules, which are simply the rules in (3) with the conditioning environment on the left rather than the right.

(4) *[+H] → [+contour] / [-H] ___ (H → F / {L,R} ___)
*[-H] → [+contour] / [+H] ___ (L → R / {H,F} ___)

Unlike the common rules in (2), such rules are totally non-existent in the languages of the world. The "[±contour]" theory thus makes a bad prediction, that certain processes should exist when they do not, and in addition the theory provides no way to express certain very natural processes, in particular processes where the conditioning environment is on the left. Finally, even for the two processes which the theory can formalize in (3), there is an unexplained element of arbitrariness — why should a H tone become a falling tone before [-H]? Those processes are formally just as simple to express as the rules in (5), and should therefore be found as commonly as the former set of rules, but in fact this latter set of rules is completely unattested.

(5) c. [+H] → [+contour] / ___ [+H] (H → F / __ {H,F})
d. [-H] → [+contour] / ___ [-H] (L → R / __ {L,R})

It is obvious that this theory of tone is wrong, but what is the alternative? There was a long-standing intuition that contour tones were in some sense composite tones, so that a rise was simply a combination of a L followed by a H, and a fall is a combination of a H followed by a L; falling and rising pitch is simply the continuous transition between the higher and lower pitch levels that H and L define. An example of the kind of phonological patterns which were responsible for this intuition is the pattern of tone changes that result from merging vowels between words in Etsako (Yekhee), illustrated below.

(6)	ídzé élà → ídzélà	'three axes'
	èké élà → èkélà	'three rams'
	údzé òkpá → údzôkpá	'one axe'
	òké òkpá → òkôkpá	'one ram'
	ówà ówà → ówǒwà	'every house'

The combination of H+L results in a falling tone, and L+H results in a rising tone. How can the intuition that fall is H+L and rise is L+H be expressed in the theory?

There is little problem in doing this for contour tones on long vowels, since long vowels can be represented as a sequence of identical vowels, so treating a long rising tone as being a sequence of tones is easy.

(7) ǎ: = àá = $\begin{bmatrix} +\text{syllabic} \\ +\text{back} \\ -\text{rd} \\ -\text{H - tone} \end{bmatrix} \begin{bmatrix} +\text{syllabic} \\ +\text{back} \\ -\text{rd} \\ +\text{H - tone} \end{bmatrix}$

The problem is short contour tones.

1.2. Autosegmental contours

A resolution of this problem was set forth in Goldsmith 1976, who proposed that tones be given an autonomous representation from the rest of the segment, so that regular segments would be represented at one level and tones would be an another level, with the two levels of representation being synchronized via **association lines**. This theory, known as **autosegmental phonology**, thus posited representations such as those in (8).

(8) á = H ǎ = L H â = H L

a a a

The representation of [á] simply says that at the same time that the rest of the vocal tract is in the configuration for the vowel [a], the larynx should be vibrating at a high rate as befits a H tone. The representation for [ǎ] on the other hand says that during the time that the rest of the vocal tract is producing the short vowel [a], the larynx should start vibrating slowly (produce a L tone) and change to a higher rate of vibration to match that specified for a H tone — this produces the smooth increase in pitch which we hear as a rising tone. The representation of [â] simply reverses the order of the tonal specifications.

The view which autosegmental phonology takes of rules is different from that taken in the classical segmental theory. Rather than viewing the processes in (2) as being random changes in feature values, autosegmental theory views these operations as being adjustments in the temporal relations between the segmental tier and the tonal tier. Thus the change in (2a) where H becomes rising after L and fall can be expressed as (9).

(9)
```
(H)  L   H                    (H)  L   H
 \   |   |        →            \   |\  |
  \  |   |                     \  | \ |
   V     V                       V   V
```

By simply adding an association between the L tone element on the left and the vowel which stands to the right, we are able to express this tonal change, without actually changing the intrinsic feature content of the string: we change only the timing relation between tones and vowels. This is notated as in (10), where the dashed association line means "insert an association line".

(10)
```
L   H
|  ·|
V   V
```

Two other notational conventions are needed to understand the formulation of autosegmental rules. First, the deletion of an association line is indicated by crossing out the line:

(11)
```
H
|
x
|
V
```

Second, an element (tone or vowel) which has no corresponding association on the other tier (vowel or tone) is indicated with the mark '′', thus, V′ indicates a toneless vowel and H′ indicates a H not linked to a vowel.

One striking advantage of the autosegmental model is that it allows us to express this common tonal process in a very simple way. The theory also allows each of the remaining processes in (2) to be expressed equally simply — in fact,

essentially identically, as involving an expansion of the temporal domain of a tone either to the left or to the right.

(12) H L (=(2b)) H L (=(2c)) L H (= (2d))

V V V V V V

The problem of the natural classes formed by contour tones and level tones was particularly vexing for the linear theory. Most striking was the fact that what constitutes a natural class for contour tones depends on the linear order of the target and conditioning tones. If the conditioning tones stand on the left, then the natural classes observed are {L,F} and {H,R}, and if the conditioning tones stand on the right, then the natural groupings are {L,R} and {H,F}. In all other cases, the groupings of elements into natural classes are independent of whether the target is to the right or the left of the trigger. The autosegmental representation of contour tones thus provides a very natural explanation of what is otherwise a quite bizarre quirk in the concept "natural class".

The autosegmental model also provides a principled explanation for the nonexistence of rules such as (4), i.e. the rules H → F / {L,R} ___ and L → R / {H,F} ___. The change of H to F after L would involve not just an adjustment in the temporal organisation of a L-H sequence, but would necessitate the insertion of a separate L to the right of the H tone, which would have no connection with the preceding L; the change of H to F after R is even worse in that the change involves insertion of L when H is remotely preceded by a L. Thus, the closest that one could come to formalising such a rule in the autosegmental approach would be as in (13).

(13) L (H) H → L (H) H L

V V V V

As we will discuss in this chapter, autosegmental theory resulted in a considerable reconceptualization of phonological processes, and allowed the theory of rules to be considerably constrained so that such rules which perform arbitrary actions in arbitrary contexts simply were rendered formally impossible to state.

In addition to the fact that the theory provides a much-needed account of contour tones, quite a number of other arguments can be given for the autosegmental theory of tone. The essential claim of the theory is that there is not a one-to-one relation between the number of tones in an utterance and the number of vowels: a single tone can be associated to multiple vowels, or a single vowel can have multiple tones. Moreover, an operation on one tier, such as the deletion of a vowel, does not entail a corresponding deletion on the other tier. We will look at a number of arguments for the autonomy of tones and the vowels which phonetically bear them in the following sections.

1.3. Tone Preservation

One very common property exhibited by tones is **stability**, where the deletion of a vowel does not result in the deletion of the tone born by the vowel. Very commonly, the tone of a deleted vowel is transferred to the neighboring vowel, often resulting in a contour tone. We have seen an example of this phenomenon in Yekhee, where the combination of a L vowel plus H vowel results in a rising toned vowel, and H+L gives a falling toned vowel.

(14) òké òkpá → òkôkpá ‘one ram’
ówà ówà → ówǒwà ‘every house’

In the autosegmental theory, deletion of a vowel does not directly affect the tone which was associated to it, and as a result, after deletion of the vowel the tone simply remains on the tonal tier with no association to the segmental tier — such an unassociated tone is referred to as a **floating** tone.

(15)
```
L  H  L   H        LH L   H          H   L  H   L        H LH   L
|  |  |   |        |   |   |          |   |  |   |        |   |   |
o k e  o kp a  →   o k o kp a         o w a  o w a  →    o w o w a
```

One of the principles proposed in this theory is that all vowels must (eventually) bear some tone, and all tones must be born by some vowel — this condition is known as the **Wellformedness Condition**. Accordingly, the unassociated tones which resulted from the deletion of a vowel would then be associated to the following vowel, resulting in a falling or rising tone.

(16)
```
LH L   H                H LH   L
|  \   |                |   \   |
o k o kp a              o w o w a
```

The combination of two like-toned vowels, as in the case of *èké élà* → *èkélà* ‘three rams’, brings out another principle of the theory. By the operation of vowel deletion and re-association of the floating tone, one would expect the following representation.

(17)
```
L H H L
|  V  |
e k e l a
```

This would not be distinct from the simple tone melody LHL: (17) says that the vowel *e* should be produced at high pitch at the beginning and at the end, with no

other pitches being produced. The **Twin Sister Convention** was proposed as a constraint on the theory, so that such a phonetically indistinguishable representation is formally disallowed.

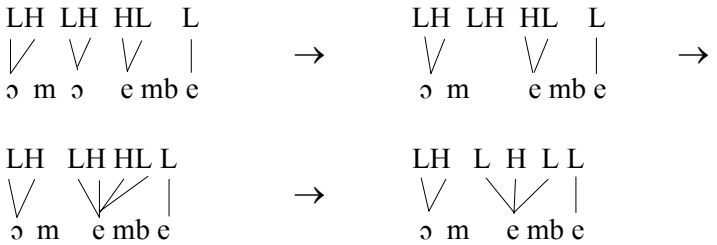
(18) *Twin Sister Convention*
Adjacent identical tones on one vowel are automatically simplified

Another illustration of the autosegmental treatment of tone preservation comes from Lomongo. When vowels are brought together, either directly in the underlying representation or as the result of deleting certain consonants, the vowel sequence is reduced to a single vowel which preserves all of the component tones of the two vowels. This can result not just in the simple contours R and F, but also the complex three-tone contours fall-rise (FR) and rise-fall (RF).

(19)	H+H → H	bètámbá béfé	→	bètámbéfé	'two trees'
	L+L → L	là ìtókò	→	lìtókò	'with the fork'
	H+L → F	mpùlú ìnɛ́	→	mpùjwînɛ́	'these birds'
	L+H → R	là bɔ́nà	→	lɔ̌nà	'with the baby'
	H+F → F	sóngóló ɔ̂tswɛ̀	→	sóngólɔ̂tswɛ̀	'may S. enter'
	H+R → FR	bàlóngá bǎkáé	→	bàlóngá͡ káé	'his blood'
	L+F → RF	fàkàlà ɔ̂tswà	→	fàkàlɔ̂͡ tswà	'F. comes in'
	L+R → R	bǎnkò bǎmɔ̌	→	bǎnkǎmɔ̌	'those others'
	R+F → RF	ɔ̌mɔ̂ êmbè	→	ɔ̌mê͡ mbè	'may someone else sing'

The derivation of the last example illustrates how the autosegmental theory explains the pattern elegantly. In this case, the first vowel deletes, causing its two tones to become floating. Those tones are associated to the following vowel by the Wellformedness Conditions. This results in two adjacent H tones on one vowel, which by the Twin Sister Convention reduce to one H, giving the phonetic output.

(20)



The fact that the theory effortlessly handles three-tone contours, when the linear theory struggled to handle even two-tone contours, is clear evidence that autosegmental theory is the better theory.

1.4. Across-the-board effects

Another phenomenon which argues for the autosegmental representation of tone is across-the-board tone change. An illustration of such a tonal effect can be found in Shona. The examples in (21) show that if a noun begins with some number of H tones, those H's become L when preceded by one of the prefixes *né-, sé-* and *ché*.

(21)

N	with N	like N	of N	Gloss
mbwá	né-mbwà	sé-mbwà	ché-mbwà	dog
hóvé	né-hòvè	sé-hòvè	ché-hòvè	fish
mbúndúdzí	né-mbùndùdzì	sé-mbùndùdzì	ché-mbùndùdzì	army worm
hákátà	né-hàkàtà	sé-hàkàtà	ché-hàkàtà	bones
bénzíbvùnzá	né-bènzìbvùnzá	sé-bènzìbvùnzá	ché-bènzìbvùnzá	fool

As shown in (22) and by the last example of (21), a H tone which is not part of an initial string of H's will not undergo this lowering process.

(22)

N	with N	like N	of N	Gloss
mùrúmé	né-mùrúmé	sé-mùrúmé	ché-mùrúmé	man
bàdzá	né-bàdzá	sé-bàdzá	ché-bàdzá	hoe

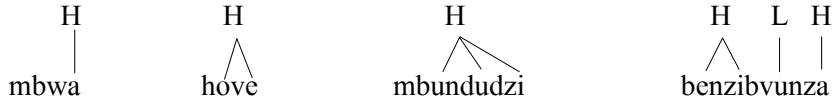
The problem is that if we look at a word such as *mbúndúdzí* as having three H tones, then there is no way to apply the lowering rule to the word and get the right results. Suppose we apply the following rule to a standard segmental representation of this word.

(23)
$$\underset{[+H]}{V} \rightarrow [-H] \;/\; \underset{[+H]}{\text{se,ne,che}}\ \_\_\_$$

Beginning from /né-mbúndúdzí/, this rule would apply to the first H toned vowel giving *né-mbùndúndzí*. However, the rule could not apply again since the vowel of the second syllable is not immediately preceded by the prefix which triggers the rule. And recall from examples such as *né-mùrúmé* that the rule does not apply to non-initial H tones.

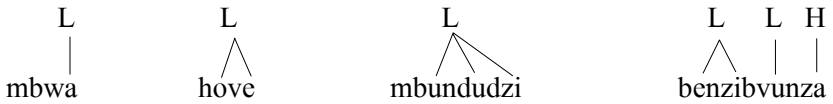
This problem has a simple solution in autosegmental theory, where we are not required to represent a string of *n* H-toned vowels as having *n* H tones. Instead, these words can have a single H tone which is associated to a number of vowels.

(24)



Given these representations, the tone lowering process will only operate on a single tone, the initial tone of the noun, but this may be translated into an effect on a number of adjacent vowels.

(25)



There is a complication in this rule which gives further support to the autosegmental account of this process. Although this process lowers a string of H tones at the beginning of a noun, when one of these prefixes precedes a prefixed structure, lowering does not affect every initial H tone. When one prefix precedes another prefix which precedes a noun with initial H's, the second prefix has a L tone and the noun keeps its H tones.

(26)

N	of N	like of N	gloss
mbúndúdzí	ché-mbùndùdzì	sé-chè-mbúndúdzí	army worm
hákátà	ché-hàkàtà	sé-chè-hákátà	bones

However, if there are three of these prefixes, the second prefix has a L tone, and lowering also affects the first (apparent) string of tones in the noun.

(27)

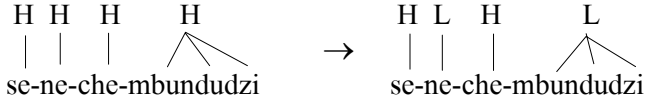
sé-nè-ché-mbùndùdzì	like with of army worm
sé-nè-ché-hàkàtà	like with of bones

A simple statement like "lower a sequence of adjacent H's" after a H prefix would be wrong, as these data show. What we see here is an alternating pattern, which follows automatically from the rule that we have posited and the autosegmental theory of representations. Consider the derivation of a form with two prefixes.

(28)

The lowering of H on *che* gives that prefix a L tone, and therefore that prefix cannot then cause lowering of the H's of the noun. On the other hand, if there are three such prefixes, the first H toned prefix causes the second prefix to become L, and that prevents prefix number 2 from lowering prefix 3. Since prefix 3 keeps its H tone, it therefore can cause lowering of H in the noun.

(29)



Thus it is not simply a matter of lowering the tones of any number of vowels. Unlike the traditional segmental theory, the autosegmental model provides a very simple and principled characterization of these patterns of tone lowering.

1.5. Melodic patterns

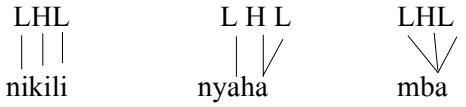
Another phenomenon which supports the autonomy of tones and segments is the phenomenon of melodic tonal restriction. In some languages, there are restrictions on the possible tones of words, irrespective of the number of vowels in the word. Mende is an example of such a language. Although this language has H, L, rising, falling and rise-falling tones, the distribution of those tones in words is quite restricted. Words can be analysed as falling into one of five tone melodies, illustrated in (30).

(30)	H	pɛ́lɛ́ ‘house’, kɔ́ ‘war’
	L	bɛ̀lɛ̀ ‘trousers’, kpà ‘debt’
	HL	kényà, mbû ‘owl’
	LH	nìká, mbǎ ‘rice’
	LHL	nìkílì ‘groundnut’, nyàhâ ‘woman’, mbǎ̂ ‘companion’

If tones were completely unrestricted, then given five surface tones, one would predict 25 patterns for bisyllabic words and 125 patterns for trisyllabic words. Instead, one finds 5 patterns no matter how many vowels there are.

This distribution can be explained if the restriction is simply stated at the level of the tonal representation: the tone pattern must be one of H, L, LH, HL or LHL. As seen in (31), given an autosegmental representation of tone, *nìkílì, nyàhâ* and *mbǎ̂* all have the same tonal representation.

(31)



1.6. Floating tones

Another tonal phenomenon which confounds the segmental approach to tone but is handled quite easily with autosegmental representations is the phenomenon of floating tones, which are tones not linked to a vowel.

Anlo tone. The Anlo dialect of Ewe provides one example. The data in (32) illustrate some general tone rules of Ewe. Underlyingly, the noun “buffalo” is /ētō/. However, it surfaces as [ètò] either phrase-finally or when the following word has a L tone.

(32)	ètò	'buffalo'	ètò mè	'in a buffalo'
	ētō φēφlē	'buffalo-buying'	ētō dyí	'on a buffalo'
	ētō mēgbé	'behind a buffalo'		

These alternations are explained by two rules; one rule lowers M to L at the end of a phrase, and the second assimilates M to a following L.

(33) M → L / ___# M → L / ___L

Thus in the citation form, /ētō/ first becomes *ētò*, then [ètò].

Two other tone rules are exemplified by the data in (34).

(34)	ètó	'mountain'	ètó dyí	'on a mountain'
	ètő mḗgbé	'behind a mountain'		

Here, we see a process which raises M to Superhigh tone (SH) when it is surrounded by H tones; subsequently a non-final H tone assimilates to a preceding or following SH tone.

(35) M → SH / H __ H H → SH % SH__

We know from *ētō mēgbé* that *mēgbé* has the tones MH. Therefore, the underlying form of *ètő mḗgbé* is *ètó mēgbé*. The underlying form is subject to the rule raising M to SH since the M is surrounded by H tones, giving *ètó mḗgbé*. This undergoes the SH assimilation rule. Another set of examples illustrating these tone processes is (36), where the noun /àtyíkē/ ends in the underlying sequence HM. When followed by /mēgbé/, the sequence HMMH results, so this cannot undergo the M raising rule. However, when followed by /dyí/, the M raising rule applies to /kē/, giving a SH tone, and the preceding syllable then assimilates this SH.

(36)	àtyíkè	'root'	àtyíkē φēφlē	'root-buying'
	àtyíkē mēgbé	'behind a root'	àtyḯkḗ dyí	'on a root'

There are some apparently problematic nouns which seem to have a very different surface pattern. In the citation form, the final M tone does not lower; when followed by the MM-toned participle /φēφlē/, the initial tone of the participle mysteriously changes to H; the following L toned postposition *mè* inexplicably has a falling tone; the postposition /mēgbé/ mysteriously has an initial SH tone.

(37)	ētō	'mortar'	ētō φéφlē	'mortar-buying'
	ētō mê	'in a mortar'	ētō dyí	'on a mortar'
	ētō mḗgbé	'behind a mortar'		

All of these mysteries are resolved, once we recognise that this noun actually does not end with a M tone, but rather ends with a H tone that is not associated to a vowel, thus the underlying form of the noun "mortar" is (38).

(38)
```
e t o
| |
M M H
```

Because the noun ends in a (floating) H tone and not a M tone, the rule lowering prepausal M to L does not apply, which explains why the final tone does not lower. The floating H associates to the next vowel if possible, which explains the appearance of a H on the following postposition as a falling tone (when the postposition is monosyllabic) or level H (when the next word is polysyllabic). Finally, the floating H serves as one of the triggering tones for the rule turning M into SH, as seen in *ētō mégbé*. The hypothesis that this word (and others which behave like it) ends in a floating H tone thus provides a unified explanation for a range of facts that would otherwise be inexplicable. However, the postulation of such a thing as a "floating tone" is possible only assuming the autosegmental framework.

Mixtec. Another example of floating tones can be seen in the language Mixtec. As the data in (39) indicate, some words such as "will eat" in the lefthand column have no effect on the tone of the following word, but other words such as the apparently homophonous verb "will go away" cause the initial tone to become H.

(39)

sùčí	'child'		
kōò	'snake'		
kēē	'will eat'	kēē	'will go away'
kēē sùčí	'the child will eat'	kēē súčí	'the child will go away'
kēē kōò	'the snake will eat'	kēē kóò	'the snake will go away'

A similar effect is seen in (40), where "all" has no effect on the following word, but "that" causes raising of the initial tone of the next word.

(40)

tàká sùčí	'all the children'	máá súčí	'that child'
tàká bēʔē	'all the houses'	máá béʔē	'that house'
tàká kōò	'all the snakes'	máá kóò	'that snake'
tàká mìnī	'all the puddles'	máá mínī	'that puddle'

These data can be explained very easily if we assume the following underlying representations.

(41)

MM	MMH	L H	HH H
k e e	k e e	t a k a	m a a

Gã. Other evidence for floating tones comes from Gã, as shown in Paster 2000. In this language, there is a rule changing the tone sequence HL at the end of a phrase into H!H. The operation of this rule can be seen in the data of (42), where the presence of the future tense prefix *baá* causes a change in the tone of final L-toned verbs with the shape CV.

(42)

3s. past	*3s future*	
e-ča	e-baá-!čá	'dig'
e-ǰo	e-baá-!ǰó	'dance'
e-gbe	e-baá-!gbé	'kill'
e-kpɛ	e-baá-!kpɛ́	'sew'
e-šɔ̃	e-baá-!šɔ̃́	'pull'
e-tũ	e-baá-!tṹ	'jump'
e-wo	e-baá-!wó	'wear'

The necessity of restricting this rule to a HL sequence which is at the end of a phrase is demonstrated by examples such as *ebaágbe Ako* "he will kill Ako", *ebaákpɛ ataadé* "he will sew a shirt", *ebaášɔ̃ kpaŋ* "he will pull a rope", where the sequence is not prepausal. This restriction also explains why verbs with long vowels or two syllables do not undergo this alternation: the L toned syllable that comes after the H is not also at the end of the phrase

(43)

3s. past	*3s. future*	
e-gbɔɔ	e-baá-gbɔɔ	'hunt'
e-hao	e-baá-hao	'worry'
e-sɔɔ	e-baá-sɔɔ	'catch'
e-sɔle	e-baá-sɔle	'pray'
e-hala	e-baá-hala	'chose'

A final condition on this rule is that it does not apply to tense-inflections on verbs, for example the plural imperative *-a* (*nyɛ̃́-hé-a* "buy (pl.)!") or the habitual *-ɔ* (*e-mãjé-ɔ* "he sends").

A second relevant rule is Plateauing, whereby HLH becomes H!HH. This can be seen in (44) involving verbs with final HL.[1] When the following object begins with a H tone, the resulting HLH sequence becomes H!HH.

[1] In these examples, the rule changing prepausal HL to H!H does not apply to the verb in citation form because the L tone is in a tense suffix.

(44)	nyɛ̃́-hé-a	"buy (pl.)!"
	nyɛ̃́-hé-ꜜá tṹ	"buy (pl.) a gun!"
	nyɛ̃́-hé-a fɔ	"buy (pl.) oil!"
	e-mãjé-ɔ ako	"he sends Ako"
	e-mãjéꜜɔ́ ákú	"he sends Aku"
	mĩ́ŋgbe kwakwɛ́	"I am killing a mouse"
	mĩ́ŋꜜgbé fóte	"I am killing a termite"

This rule also applies within words, when the verb stem has the underlying tone pattern LH and is preceded by a H toned prefix.

(45)	*3s. past*	*3s. future*	
	e-hulú	e-baáꜜ-húlú	"jump"
	e-kasé	e-baáꜜ-kásé	"learn"
	e-kojó	e-baáꜜ-kójó	"judge"
	e-mãjé	e-baáꜜ-mãjé	"send"

There are a number of areas in the language where floating tones can be motivated. The perfective tense provides one relevant example. Consider the data in (46), which contrasts the form of the subjunctive and the perfective. Segmentally these forms are identical: their difference lies in their tone. In both tenses the subject prefix has a H tone. In the perfective, the rule affecting prepausal HL exceptionally fails to apply to a L toned CV stem, but in the subjunctive that rule applies as expected.

(46)	*3s. subjunctive*	*3s. perfective*	
	é-ꜜčá	é-ča	'dig'
	é-ꜜjó	é-jo	'dance'
	é-ꜜgbé	é-gbe	'kill'
	é-ꜜkpɛ́	é-kpɛ	'sew'
	é-ꜜšṍ	é-šõ	'pull'
	é-ꜜwó	é-wo	'wear'

You might think that the perfective is an exception, but there is more to it than that.

Another anomaly of these verbs forms is that the Plateauing rule fails to apply between the verbs of (46) and an initial H tone, even though the requisite tone sequence is found.

(47) é-gbe ákú 'he has killed Aku'
é-šɔ̃ gú$^{!}$gɔ̃́ 'he has pulled a nose'
é-wo ǰwɛ́$^{!}$ɛ́ 'he has worn grass'

The failure of both the HL → H$^{!}$H rule and the Plateauing rule can be explained by positing that the perfective tense is marked by a floating L tone which comes between the subject prefix and the verb stem; thus the phonological representation of perfective *é-wo* would be (48).

(48)
```
H  L   L
|      |
e  -  wo
```

The floating L between the H and the L of the root means that the H is not next to the prepausal L, which we have already seen is a crucial condition for the change of HL to H$^{!}$H. In addition, the presence of this floating L explains why this verb form does not undergo Plateauing. Thus two anomalies are explained by the postulation of a floating tone.

Other examples of the failure of the Plateauing rule in this tense can be seen below. The examples from the simple past show that these verbs underlyingly have the tone pattern LH, which surfaces unchanged after the L toned subject prefix used in the simple past. The subjunctive data show that these stems do otherwise undergo Plateauing after a H toned prefix; the perfective data show that in the perfective tense, Plateauing fails to apply within the word.

(49)

3s. past	*3s. subjunctive*	*3s perfective*	
e-hulú	é$^{!}$-húlú	é-hulú	"jump"
e-kasé	é$^{!}$-kásé	é-kasé	"learn"
e-kojó	é$^{!}$-kójó	é-kojó	"judge"
e-mãjé	é$^{!}$-mãjé	é-mãjé	"send"

Again, these facts can be explained by positing a floating tone in the perfective tense: that L means that the actual tone sequence is HLLH, not HLH, so Plateauing would simply not be applicable to that tone sequence.

(50)
```
H L L H
|     | |
e -  hulu
```

Finally, the postulation of a floating L as the marker of the perfective explains why a downstep spontaneously emerges between the subject prefix and a stem initial H tone.

(51)	*3s. past*	*3s. subjunctive*	*3s perfective*	
	e-bé	é-bé	ɛ́ˡ-bé	quarrel
	e-chṹ	é-chṹ	ɛ́ˡ-chṹ	send
	e-dṹ	é-dṹ	ɛ́ˡ-dṹ	cultivate
	e-fó	é-fó	ɛ́ˡ-fó	weep
	e-fɔ́té	é-fɔ́té	ɛ́ˡ-fɔ́té	pour
	e-jálé	é-jálé	ɛ́ˡ-jálé	rinse

Thus the postulation of a floating tone as the marker of the perfective explains a number of anomalies: insofar as floating tones have a coherent theoretical status in autosegmental phonology but not in the linear theory, they provide strong support for the correctness of the autosegmental model.

1.7. Tonal Morphemes

Another example of the kind of dissynchrony between tones and vowels which is explained by the autosegmental model is the tonal morpheme, where a particular morpheme is expressed solely as a tone — this is a variant of the problem of floating tones. One such example is the expression of case-marking and the marking of modified nouns in Angas. When a noun is case-marked in Angas (when it is at the end of the subject or object NP, for example), case marking is indicated with a suffixed floating H which links to the final vowel, forming a rising tone if the final tone of the noun is M or L. When a noun is followed by an adjective in its phrase, that fact is marked by the suffixation of a floating L tone, which forms a falling contour tone when the last tone is M or H.

(52)	téŋ	‘rope’	téŋ	‘rope (case)’	têŋ	‘rope (modified)’
	mús	‘cat’	mús	‘cat (case)’	mûs	‘cat (mod.)’
	čén	‘hoe’	čén	‘hoe (case)’	čên	‘hoe (mod.)’
	nyí	‘elephant’	nyí	‘elephant (case)’	nyî	‘elephant (mod.)’
	ʔās	‘dog’	ʔā̋ s	‘dog (case)’	ʔā̏ s	‘dog (mod.)’
	žwāl	‘boy’	žwā̋ l	‘boy (case)’	žwā̏ l	‘boy (mod.)’
	ɟēm	‘child’	ɟē̋ m	‘child (case)’	ɟē̏ m	‘child (mod.)’
	màs	‘locust bean’	măs	‘bean (case)’	màs	‘bean (mod.)’
	pùk	‘soup’	pŭk	‘soup (case)’	pùk	‘soup (mod.)’
	ʔàs	‘tooth’	ʔăs	‘tooth (case)’	ʔàs	‘tooth (mod.)’
	ǰólì	‘ape’	ǰólǐ	‘ape (case)’	ǰólì	‘ape (mod.)’

Tiv is another language with morphemes being marked by tone, in this case verbal tense-aspect. Verb roots in Tiv lexically have either a H tone or a L tone on the first syllable of the root. The general past tense is marked with a floating L tone; the past habitual with a H; the recent past with the tone sequence HL.

(53)

H verbs		L verbs	
General Past (L)			
vá	'come'	dzà	'go'
úngwà	'hear'	vèndè	'refuse'
yévèsè	'flee'	ngòhòrò	'accept'
Past Habitual (H)			
vá		dzá	
úngwá		vèndé	
yévésé		ngòhóró	
Recent Past (HL)			
vá		dzá	
úngwá		vèndé	
yévésè		ngòhórò	

In addition to showing the effects of various floating tone morphemes which mark tense-aspect, these data illustrate the application of a contour-simplification rule. We now consider how representative forms are actually derived. The concatenation of the L root *ngohoro* and the recent past morpheme gives the following underlying form.

(54)

```
  L   H L
  |
ngohor
```

These tones must be assigned to the vowels of the stem: we can see that the first tone links to the first free vowel and the second tone links to the second free vowel. This is an instance of **one-to-one left-to-right mapping**.

(55) Link free tones to free vowels, one-to-one, from left to right

This process is so common that it had been thought that it is actually a universal convention on free tones — we now know, since languages have been discovered which do not obey this condition — that it is a language specific rule, though a very common one. Application of this rule to (54) gives the surface form.

Now consider the disyllabic L root *vèndé*. This root has two vowels but three tones. If all of the tones were to be associated to the vowels of the root, this would force the final syllable to bear the tone sequence HL, i.e. it would have a falling tone. We can see that there are no contour tones in the data. This leaves us with two possibilities in accounting for *vèndé*: either the rule associating floating tones to vowels simply does not link a floating tone to a vowel that already has a

tone, or floating tones do associate to vowels that already bear a H and then some later rule eliminates tonal contour tones. If we assume that floating tones are all initially associated to a vowel and contours are later eliminated, we will require the following rule, which deletes the L tone component of a falling tone.

(56) H L → ∅

V

Finally, we come to the monosyllabic root /dzà/, which surfaces with a H tone just in case one of the floating tone patterns H or HL is added to the root. This can be explained by the hypothesis that floating tones are associated to root vowels even when this would result in a contour tone. Linking the melodic tones to this root would result in the following representation.

(57) L H L

dza

Rule (56) applies in a mirror-image fashion, that is, it deletes L in combination with a H on a single vowel, standing either before or after the H. This explains why the lexical H tone is replaced with a H tone. If we were to assume the alternative account, that floating tones only link to vowels which do not have any other tone, then we would be unable to explain why the lexical L is replaced by H when a melodic pattern with a H tone is added.

1.8. Toneless vowels

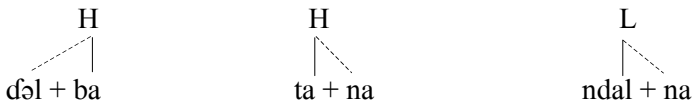
Another phenomenon demonstrating the independence of tones and vowels is the existence of underlyingly toneless vowels. This can be illustrated with data from Margyi. There are two tones in Margyi, H and L, but there are three underlying types of vowels in terms of tonal behavior, namely H, L and toneless. Examples of underlyingly toneless morphemes are /ɗəl/ "buy", /skə/ "wait" and /na/ "away". When two morphemes with underlying tones are combined, there are no surface tone changes. However, when one of the toneless morphemes is combined with a morpheme with tone, the toneless morpheme takes on the tone of the tone-bearing morpheme.

(58)	tá + bá → tábá	'to cook all'
	ndàl + bá → ndàlbá	'to throw out'
	ɗəl + bá → ɗə́lbá	'to buy'

ná + ɗà → náɗà	'give me'
hərì + ɗà → hərɗà	'bring me'
skə + ɗà → skəɗà	'wait for me'
tá + na → táná	'to cook and put aside'
ndàl + na → ndàlnà	'to throw away'
ɗəl + na → ɗəlnà	'to sell'

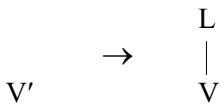
As (59) indicates, this can be accounted for by spreading tone (i.e. adding associations between tone and vowels) to toneless vowels.

(59)



The form *ɗəl-nà* 'to sell', which combines two toneless morphemes, illustrates another property of tone systems. Since all vowels must on the surface have some tonal specification, the following question arises: if there is no tone present in the string which could spread to toneless vowels, how do toneless vowels get their surface tone. The answer is that there are also rules of **default tone assignment**, which guarantee that if a vowel does not otherwise have a tone value, one is automatically assigned. Such a rule can be formalized as (60).

(60)



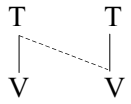
Generally, in languages with two levels of tone, the default value assigned to otherwise toneless vowels is L; in languages with three tone levels, the default tone specification is usually M tone. Yoruba is a language with three tone levels, where it can be argued that M toned vowels are actually underlyingly toneless, and M tones are assigned by a default tone assignment rule. The examples in (61) illustrate a very general tone spreading rule whereby L tone becomes falling after H, and H tone becomes rising after L. However, M is unchanged after either L or H, and M also has no effect on a following L or H.

(61)

kò pɔ̀	'it is not plentiful'	kò dùn	'it is not sweet'
ó pɔ̂	'it is plentiful'	ó dûn	'it is sweet'
ɛ̀kɔ̌	'lesson'	ɔ̀bɔ̄	'monkey'
ɔ̀fɔ̀	'mourning'	gígā	'height'
ìṣé	'work'	ẹ̄jò	'snake'

The question is how to exclude M tone from being targetted by this rule, and how to prevent M tone from spreading. If we assume that tonally unspecified vowels are assigned a M tone by default, and that M tones in Yoruba derive only from application of this default specification rule, then we can explain these patterns rather simply. We can assume the following tone spreading rule, where T represents any tone.

(62)



The fact that contours are not formed with M tone follows from the fact that a contour is two tone specifications on one vowel, plus the hypothesis that M tone is only assigned if there is no tonal specification on a vowel.

1.9. Tonal mobility

The final demonstration of the autonomy of tone from segments is the tone mobility, which is the fact that tones can move about from vowel to vowel quite easily, in a fashion not shared with segmental properties. One example of tonal mobility comes from Runyankore, seen in (63). This language has an underlying contrast between words whose last syllable is H toned, and those whose penultimate syllable is H toned. In pre-pausal position, underlyingly final H tones shift to the penultimate syllable, thus neutralizing with nouns having an underlyingly penult H. When some word follows the noun, the underlying position of the H tone is clearly revealed.

(63) *Nouns with penult H*

òkùgúrù	'leg'	òkùgúrù kùrùùnjì	'good leg'
òmùkózì	'worker'	òmùkózì mùrùùnjì	'good worker'
èmbúzì	'goat'	èmbúzì nùùnjì	'good goat'
èchìkópò	'cup'	èchìkópò chìrùùnjì	'good cup'
èmbíbò	'seeds'	èmbíbò nùùnjì	'good seeds'

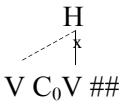
Nouns with final H

òmùgúzì	'buyer'	òmùgùzí mùrùùnjì	'good buyer'
òmùkámà	'chief'	òmùkàmá mùrùùnjì	'good chief'
èémbwà	'dog'	èèmbwá nùùnjì	'good dog'
òbúrò	'millet'	òbùró bùrùùnjì	'good millet'
kàsúkù	'parrot'	kàsùkú nùùnjì	'good parrot'

There are a number of reasons internal to the grammar of Runyankore for treating L tone as the default tone, and for only specifying H tones in the phonology so that

phonetically L tones vowels are actually toneless. This alternation can be accounted for by the following rule of tone-throwback.

(64)



Another example of tone shift can be seen in Kikuyu. Like Runyankore, there are good reasons to analyse this language phonologically solely in terms of the position of H tones, with vowels not otherwise specified as H being realised phonetically with a default L tone. We will follow the convention adopted in such cases as marking H toned vowels with an acute accent, and not marking toneless (default L) vowels.

Consider the Kikuyu data in (65) from the current habitual tense. The first two examples in (65a) would indicate that the morphemes *to-*, *-rɔr-, -aγ-* and *-a* are all toneless. The third example, however, shows the root *rɔr* with a H tone: this happens just in case the root is preceded by the object prefix *ma*. In (65b), we see that — in contrast to what we see in (65a) — the habitual suffix *-aγ-* has a H tone when it is preceded by the root *tom* (which is itself toneless on the surface). As with (65a), the syllable that follows *ma* has a H tone.

(65)	a.	to- rɔr - aγ-a we-look at-hab-tense	'we look at'
		to-mo- rɔr -aγ-a we-him-look at-hab-tense	'we look at him'
		to-ma- rɔ́r -aγ-a we-them-look at-hab-tense	'we look at them'
	b.	to-tom-áγ-a	'we send'
		to-mo-tom-áγ-a	'we send him'
		to-ma-tóm-áγ-a	'we send them'

It is clear, then, that certain syllables has the property of causing the following syllable to have a surface H tone. This is further demonstrated in (66), where the derivational suffixes *-er-* and *-an-* follow the roots *-rɔr-* and *-tom-*: we can see that the syllable after *-tom* always receives a H tone.

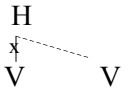
(66)	to-rɔr-er-aγ-a	'we look for'
	to-tom-ér-aγ-a	'we send for'
	to-rɔr-an-aγ-a	'we look at each other'
	to-tom-án-aγ-a	'we send each other'
	to-rɔr-er-an-aγ-a	'we look for each other'
	to-tom-ér-an-aγ-a	'we send for each other'

Further examples of this phenomenon are seen in the examples of the recent past in (67). In (67a), the root *rɔr* (which generally has no H tone) has a H tone when it stands immediately after the recent past tense prefix -*a*-; or, the object prefix that follows -*a*- will have a surface H tone. The examples in (67b) show the same thing with the root -*tom*- which we have seen has the property of assigning a H tone to the following vowel.

(67)	a.	to-a-rɔ́r-a	'we looked at'
		to-a-mó-rɔr-a	'we looked at him'
		to-a-má-rɔ́r-a	'we looked at them'
	b.	to-a-tóm-á	'we sent'
		to-a-mó-tom-á	'we sent him'
		to-a-má-tóm-á	'we sent them'

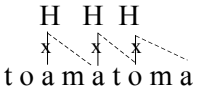
The most reasonable assumption to make is that the verbal root -*tóm*- underlyingly has a H tone, as does the object prefix -*má*- and the tense prefix -*a*-, and this H tone is subject to the following rule of tone shift, which moves every H tone one vowel to the right.

(68)



Thus, /to-tóm-er-aγ-a/ becomes *totoméraγa*, /to-má-rɔr-aγ-a/ becomes *tomarɔ́raγa*, and /to-á-má-tóm-a/ becomes *toamátómá*.

(69)



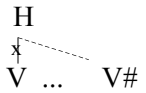
An even more dramatic example of tone shifting comes from Digo. In this language, the last H tone of a word shifts to the end of the word. The root *vugura* is toneless, as is the object prefix *ni*, but the object prefix *a* "them" has an underlying H tone, which is phonetically realised on the last vowel of the word. Similarly, the root *togora* is toneless, as is the subject prefix *ni*, but the 3rd sg. subject prefix *a* has a H tone, which shifts to the end of the word. Lastly, the root *tsukura* is toneless, as is the tense-aspect prefix -*na*-, but the perfective prefix *ka* has a H tone which shifts to the last vowel of the word.

(70)	a.	ku-vugura	'to untie'	ku-vugurira	'to untie for'
		ku-ni-vugurira	'to untie for me'	ku-a-vugurirá	'to untie for them'
	b.	ku-togora	'to praise'	ni-na-togora	'I'm praising'
		a-na-togorá	'he's praising'		

c.	ku-tsukura	'to carry'	ni-na-tsukura	'I'm carrying'
	a-na-tsukurá	'he's carrying'	ni-ka-tsukurá	'I have carried'

These data can be accounted for by a rule of tone shift which is essentially the same as the Kikuyu rule, differing only in that the tone shifts all the way to the end of the word.

(71)



2. Extension to the segmental domain

The foregoing modification of phonological theory had the obvious good consequence that tonal phenomena could be accounted for very nicely manner, whereas previously tone was largely outside the grasp of the theory. The impact of autosegmental phonology was much more profound than that, however. The obvious thing to wonder, if tones are separate from the rest of the segment, then perhaps segments themselves are not such monolithic, unstructured entities. And so investigators looked for evidence for a similar separation of segmental features.

2.1. The autonomy of all features

An example of segmental phenomena which are reminiscent of autosegmental tonal properties are floating segmental features as morphemes. One such case is seen in Vata, there the past tense marker can be argued to be simply the specification [+hi], which is suffixed to the stem and is realised phonetically on the last vowel.

(72)	n le	'I eat'	n li	'I ate'
	n plɛ	'I pass'	n plɩ	'I passed'
	n mlɛ	'I go'	n mlɩ	'I went'
	n no	'I hear'	n nu	'I heard'
	n zɔ	'I place'	n zʊ	'I placed'
	n wɔlɔ	'I wash'	n wɔlʊ	'I washed'

A second example comes from Fula, where a particular grammatical agreement pattern ('pattern B' below) is marked by a prefix composed of the segmental specification [-continuant] which causes an initial continuant to become a stop.

(73)	*pattern A*	*pattern B*	
	wecco	becce	‘rib’
	wibjo	bibje	‘wing’
	ruulde	duule	‘cloud’
	sɛkko	cɛkke	‘mat’
	hello	kelle	‘slap’
	yeɓre	jeɓel	‘seed’
	yimre	jimel	‘poem’
	yontere	jonte	‘week’

Aramaic CP. Azerbaijani Aramaic provides evidence for treating the feature [constricted pharynx] ([CP]) autosegmentally. This dialect has a contrast between pharyngealised or emphatic vowels (AEIUO) specified as [+CP], and plain vowels (aeiuo). In most words, either all of the vowels are emphatic, or none of them are.

(74)	AmrA	‘wool’	brata	‘daughter’
	zArʔA	‘seed’	bela	‘house’
	qUlOx	‘stand up!’	nũ̆jum	‘sorcery’

Some words may have non-emphatic vowels followed by emphatic vowels. In such a case, the first emphatic vowel is always a low vowel.

(75)	šarAw	‘corn growing wild’	riswAy	‘unmannerly speech’
	seyfullAh	‘a great deal’	fandbAz	‘trickster’
	nišAn	‘sign’	peštAmAl	‘towel’
	milAqE	‘hung grapes’	eliyAhU	name
	galimbAǰI	‘brother’s wife’	silAhlAmIš	‘supplied with weapons’

These distributional properties will play an important role in arguing for an autosegmental treatment of [CP].

In line with the fact that all vowels in a word generally agree in the feature [CP], (76) shows that suffixes harmonize in [CP] with the preceding vowel.

(76)	lixm-a	‘bread’	lixm-e	pl.
	pirčaxwar-a	‘old woman’	pirčaxwar-e	pl.
	nOhr-A	‘mirror’	nOhr-E	pl.
	dIqnAxwAr-A	‘old man’	dIqnAxwAr-E	pl.
	klu	‘write! (sg)’	klu-mun	pl.
	bilbul	‘seek!’	bilbul-un	pl.
	qU	‘rise!’	qU-mUn	pl.
	mIšltUn	‘make a king!’	mIšltUn-Un	pl.

[CP] will spreads through a whole sequence of suffixes.

(77)	mĭr-a	'she said'	xIt-lAx	'you (f.sg.) sewed'
	mir-wa-la	'she had said'	xIt-wA-lAx	'you had sewn'
	mir-wa-la-la	'she had said it'	xIt-wA-lAx-U	'you had sewn them'

We will assume that the only value underlyingly marked for this feature is [+CP], and that [+CP] spreads to the right by the following rule.

(78) [+CP]

V V

This rule thus explains why [+CP] vowels are always followed by [+CP] vowels. However, we also need to explain why roots with a [+CP] specification (generally) have [+CP] beginning with the first vowel. We can assume that, in the general case the specification [+CP] is not associated to any particular vowel, but is just floating, and an unassociated [+CP] specification is associated to the first vowel of the word by the following rule.

(79) [+CP]′

C_0 V

The derivation of *mIšltUn-Un* 'make a king (pl.)!' shows these rules.

(80) [+CP] (rule (79)) → [+CP] (rule (78)) → [+CP]

mišitun-un mišitun-un mišitun-un

There are some suffixes whose vowels are invariably emphatic; that vowel is always the vowel [A]. No suffixes are invariably plain.

(81)	qalăma	'pen'	qalam-dAn	'case for scribe's utensils'
	qand	'sugar'	qand-dAn	'sugarbowl'
	šakăr	'sugar'	šakăr-dAn	'sugarbowl'
	dukana	'store'	dukan-dAr	'shopkeeper'
	mewana	'guest'	mewan-dAr	'hospitable'
	ǰut	'plow'	ǰut-kAr	'plower'
	nŭǰum	'sorcery'	nŭǰum-kAr	'sorcerer'
	naqš	'engraving'	naqš-kAr	'engraver'

These suffixes will be assumed to have underlying [CP] specifications, in contrast to most other suffixes which are unspecified for [CP]. Since the suffix vowel is lexically associated with [+CP], it does not associate to the first vowel of the word, and since it does not associate to the first vowel of the word, [+CP] does not spread to any vowels before that of the suffix.

We also find spreading of [+CP] between members of a compound. In the examples of (82), [+CP] spreads from the first compound to the second.

(82)	tAhA	'3'	imme	'100'
	tAhA-mmE	'300'		
	dIqnA	'beard'	xwara	'white'
	dIqnA-xwArA	'old man'		

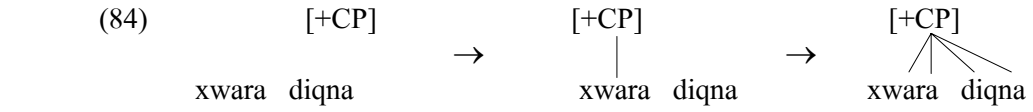
This is the expected pattern: [+CP] spreads rightward from the first member of the compound to the second.

If the second member of the compound has [+CP] vowels, [+CP] spreads through the second member of the compound.

(83)	xwara	'white'	dIqnA	'beard'
	xwArA-dIqnA	'old man'		
	be	'without'	hAd	'limit'
	bEhAd	'exceedingly'		
	qahwa	'coffee'	xAnA	'shelter'
	qAhwA-xAnA	'coffee-room'		

This apparent exceptional leftward spreading of [+CP] is nothing of the sort. Rather, the second member of the compound has a floating [+CP] specification; in a compound, that feature links to the first vowel of the word by rule (79), and then spreads to the right.

(84)



Another case of [+CP] appearing to the left of the morpheme where it originates is seen in (85), where a prefix is added to a root with a floating [+CP] specification.

(85)	xoš	'good'	na-xoš	'ill'
	hAq	'right'	nA-hAq	'wrong'
	rAzI	'satisfied'	nA-rAzI	'unsatisfied'

pyala	‘fall’	ma-pole	‘cause to fall’
šatoe	‘drink’	ma-stoe	‘give drink’
myAsA	‘suck’	mA-mOsE	‘give the suck’
rAdOxE	‘boil (intr.)’	mA-rdOxE	‘boil (tr.)’

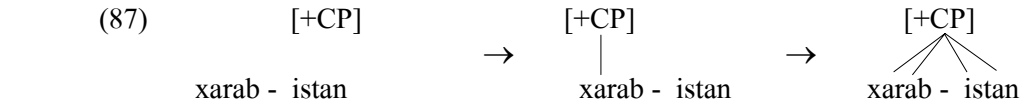
Given the assumption that a root specification of [+CP] is not generally associated in the underlying form (except in roots such as (75) where [+CP] is unpredictably associated to a non-initial low vowel), our analysis predicts that the [+CP] specification will link to the first vowel of the word, which will be the prefix vowel in this case, and spreads to the right thereafter.

The locational suffix -*istan* has the interesting property that it causes all vowels in the word to which it is attached to become [+CP].

(86)	xaraba	‘ruined’	xArAb-IstAn	‘ruined place’
	čol	‘uninhabited land’	čOl-IstAn	‘wilderness’
	hind	‘India’	hInd-IstAn	‘India’

This makes sense if the suffix -*istan* also has a floating specification [+CP], which automatically associates to the first vowel of the stem and then spreads rightward.

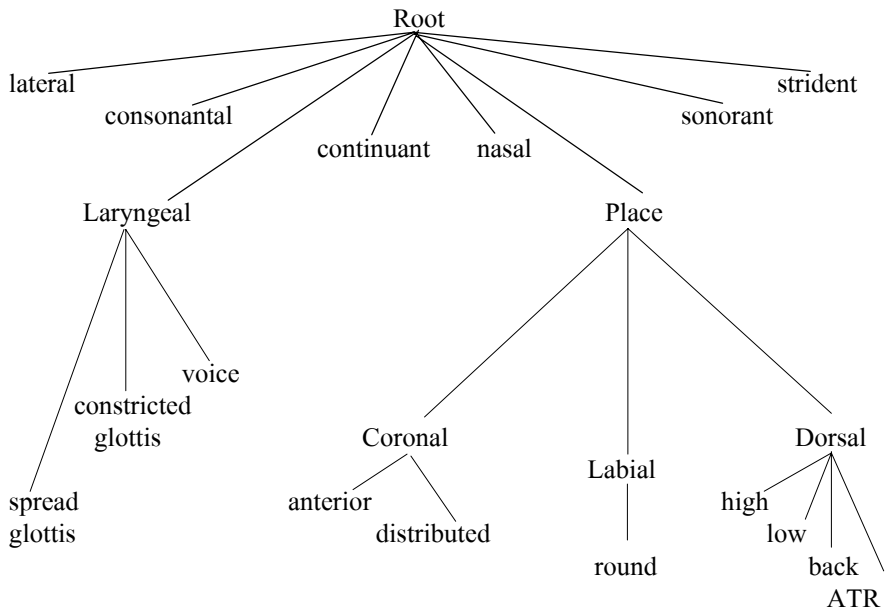
(87)



2.2. Feature geometry

It was soon realized that an autosegmental account of all features could be given — that in principle, all features are autonomous from all other features, and could exhibit the kind of behavior which motivated the autosegmental treatment of tone. The question then arises as to exactly how features are arranged, and what they associate to, if the “segment” has had all of its features removed. The generally accepted theory of how features relate to each other is expressed in terms of a feature-tree such as (88). This tree — known as a **feature geometry** — expresses the idea that while all features express a degree of autonomy, certain subsets of the features form coherent phonological groups, as expressed by their being grouped together into constituents such as “Laryngeal” and “Place”.

(88)



The organisation of features into such a structure went hand-in-hand with the realization that the theory of rules could be constrained in very important ways. A long-standing problem in phonological theory was the question of how to express rules of multiple-feature assimilation. Such rules are extremely common, and one such example can be seen in Kimatuumbi. In this language, a nasal consonant agrees in place of articulation with the following consonant. In the following examples, the plural noun prefix is underlyingly /ñ/ and appears as such before a vowel, but assimilates to a following consonant.

(89)	*singular*	*plural*	
	lw-aámbo	ñ-aámbo	"bead"
	lɥ-góị	ŋ-góị	"rope"
	lɥ-báɥ	m-báɥ	"rib"
	lɥ-ǰịịŋgyá	ñ-ǰịịŋgyá	"entered"
	lɥ-laála	n-daála	"pepper"

The question is, how can this rule be formally expressed? It is a simple matter to write a rule assimilating a nasal to a single place of articulation, so for example a rule which changes /ñ/ into [m] before a labial could be written as (90a), or a rule changing /ñ/ to [ŋ] before a velar could be written as (90b).

(90) a. $$[+\text{nasal}] \rightarrow \begin{bmatrix} +\text{anterior} \\ -\text{cororal} \end{bmatrix} / \_\_ \begin{bmatrix} +\text{anterior} \\ +\text{coronal} \end{bmatrix}$$

b. $$[+\text{nasal}] \rightarrow \begin{bmatrix} +\text{hi} \\ +\text{back} \\ -\text{cororal} \end{bmatrix} / \_\_ \begin{bmatrix} +\text{hi} \\ +\text{back} \\ -\text{coronal} \end{bmatrix}$$

However, it was impossible to write a single rule to express both changes, since the actual feature values assigned to a nasal are not constant — they depend on the feature value of the following segment.

Since such assimilations are quite common, formal machinery was introduced into the theory which made it possible to account for such cases where the actually assigned values are variable. **Feature variables** (also know as **alpha notation**) were also available in the linear theory, and are defined as follows.

(91) Each occurrence of an individual variable (α, β, γ...) is replaced with the value "plus", or each occurrence of the variable is replaced with "minus".

Thus a rule containing a variable is really an abbreviation for two rules, one containing plusses for a given variable and one containing minuses. A rule containing a variable is known as a **metarule**, which it is an expression referring to a class of **simple** rules containing no variables. Thus the metarule in (92a) expands to (is an abbreviation of) the simple rules in (92b).

(92) a. $$C \rightarrow [\alpha\text{voice}] / \_\_\_ [\alpha\text{voice}]$$

b. $$\left\{ \begin{array}{l} C \rightarrow [+\text{voice}] / \_\_\_ [+\text{voice}] \\ C \rightarrow [-\text{voice}] / \_\_\_ [-\text{voice}] \end{array} \right\}$$

Each variable is expanded independent of other variables, so the metarule (93a) expands into the four simple rules (93b).

(93) a. $$C \rightarrow \begin{bmatrix} \alpha\text{voice} \\ \beta\text{nasal} \end{bmatrix} / \_\_\_ \begin{bmatrix} \alpha\text{voice} \\ \beta\text{nasal} \end{bmatrix}$$

b. $$\left\{\begin{array}{l} C \rightarrow \begin{bmatrix} +\text{voice} \\ +\text{nasal} \end{bmatrix} / \_\_ \begin{bmatrix} +\text{voice} \\ +\text{nasal} \end{bmatrix} \\ C \rightarrow \begin{bmatrix} +\text{voice} \\ -\text{nasal} \end{bmatrix} / \_\_ \begin{bmatrix} +\text{voice} \\ -\text{nasal} \end{bmatrix} \\ C \rightarrow \begin{bmatrix} -\text{voice} \\ +\text{nasal} \end{bmatrix} / \_\_ \begin{bmatrix} -\text{voice} \\ +\text{nasal} \end{bmatrix} \\ C \rightarrow \begin{bmatrix} -\text{voice} \\ -\text{nasal} \end{bmatrix} / \_\_ \begin{bmatrix} -\text{voice} \\ -\text{nasal} \end{bmatrix} \end{array}\right\}$$

Using this variable notation, a general form for a rule of nasal place-assimilation can be given as in (94).

(94) $$C \rightarrow \begin{bmatrix} \alpha\text{coronal} \\ \beta\text{anterior} \\ \gamma\text{back} \\ \delta\text{high} \\ \theta\text{distributed} \end{bmatrix} / \_\_ \begin{bmatrix} \alpha\text{coronal} \\ \beta\text{anterior} \\ \gamma\text{back} \\ \delta\text{high} \\ \theta\text{distributed} \end{bmatrix}$$

The one good thing that can be said about this addition to the theory is that it does allow formalisation of rule which exists, and which could not be formalized (within the linear theory) if there were no such notation.

However, the notation also makes some very bad predictions. First, notice that complete place assimilation requires specification of ten features in total. Formally speaking, this rule is less simple, and given the principle of rule simplicity employed in that theory, should occur less frequently, than a rule such as (95).

(95) C → [αcoronal] / ___ [αcoronal]

Thus the prediction is that rule (95) should be a much more common rule. This prediction is totally wrong: a rule like (95) is not just uncommon, it is completely unattested. Were there to be such a rule that assimilates only the specification of coronal, we would expect to find sets of assimilations such as the following.

(96)

mč → nč (not ñč)	ŋč → ñč
ñp → ŋp	np → mp
ñk → ŋk	nk → mk
ñt → ñt	nč → nč

The fact that the feature-variable theory allows us to formulate such an unnatural process at all, and assigns a much higher probability of occurrence to such a rule, is a sign that something is wrong with the theory.

The theory says that there is only be a minor difference in naturalness between (97) and (94), since the rules are the same except that (97) does not include assimilation of the feature [anterior].

$$\text{(97)} \qquad C \rightarrow \begin{bmatrix} \alpha\text{coronal} \\ \gamma\text{back} \\ \delta\text{high} \\ \theta\text{distributed} \end{bmatrix} / \_\_ \begin{bmatrix} \alpha\text{coronal} \\ \gamma\text{back} \\ \delta\text{high} \\ \theta\text{distributed} \end{bmatrix}$$

Yet there is a huge empirical difference between these two rules: (94) is very common, (97) is unattested. Rule (97) is almost a complete place-assimilation rule, except that anteriority is not assimilated, and thus /np/, /ñk/ and /mt/ would become [mp], [ŋk] and [nt] as expected, but /ñt/ and /nč/ would not undergo assimilation (as they would have under complete place assimilation); similarly, /ŋč/ would become [ñč] as expected (and as well-attested), but /ŋp/ and /ŋt/ would become [ṇp] and [ṇt], since the underlying value [-anterior] from /ŋ/ would not be changed. Thus the inclusion of feature variables in the theory incorrectly predicts the possibility of many types of rules which do not exist in human language.

Another problem with the variable-feature theory is that it does not give any special status to a rule where both occurrences of α occur on the same feature, versus on different features. You can just as easily have a rule such as the following in feature-variable theory, where the variables on the structural change are shifted down by one feature in the specification of the context.

$$\text{(98)} \qquad C \rightarrow \begin{bmatrix} \alpha\text{coronal} \\ \beta\text{anterior} \\ \gamma\text{back} \\ \delta\text{high} \\ \theta\text{distributed} \end{bmatrix} / \_\_ \begin{bmatrix} \theta\text{coronal} \\ \alpha\text{anterior} \\ \beta\text{back} \\ \gamma\text{high} \\ \delta\text{distributed} \end{bmatrix}$$

This rule describes an equally unnatural and unattested process whereby a consonant becomes [t] before [p^y], [p] before [q], and [p^y] before [k]. Rules such as (98) do not exist in human language, which indicates that the linear theory which uses this notation as a means of expressing assimilations makes poor predictions regarding the nature of phonological rules.

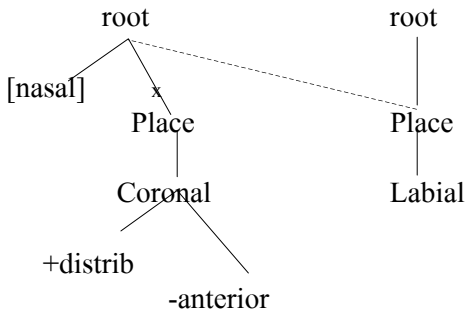
Equally bad is the fact that the variable notation allows us to refer to legions of unnatural classes by randomly linking two unrelated features with a single variable:

(99) a. $\begin{bmatrix} \alpha\text{high} \\ \alpha\text{round} \end{bmatrix}$ b. $\begin{bmatrix} \alpha\text{distributed} \\ \alpha\text{nasal} \end{bmatrix}$ c. $\begin{bmatrix} \alpha\text{coronal} \\ \alpha\text{anterior} \end{bmatrix}$ d. $\begin{bmatrix} \alpha\text{voice} \\ \alpha\text{lateral} \end{bmatrix}$

Class (a) applied to vowels would refer to [ü,u,e,ə,a]; (b) would refer to [n̪,ñ,p,t̪,k] but would exclude [m,n̩,t̪,č,ŋ]; (c) groups together [t,k] and excludes [p,č]; (d) refers to [l] plus voiceless consonants. Such groupings do not constitute natural classes, and such groupings are not attested in any language. Indeed, were such groupings to be found, one would rightly question the very correctness of distinctive feature theory itself.

With the advent of a theory of feature geometry such as in (88), this problem disappeared. In that theory, the process of place assimilation is fomulated not as the change of one feature value into another, but is expressed as the spreading of one node — in this case the Place node — at the expense of another place node. Thus the change /ñ/ → [m] / __ [p] is seen as working as in (100).

(100)



Just tone assimilation is the rightward or leftward expansion of the domain of a tone feature, this process of place assimilation is expansion of the domain of one set of place specifications, to the exclusion of another. When one Place node spreads and replaces the Place node of a neighboring segment, that means that all of the original place features are deleted, and the segment then comes to bear the entire set of place features that the neighboring segment has.

What the feature variable notation was able to do was express multiple-feature assimilations, but given this alternative theory, multiple feature assimilations will be recast as spreading some node such as Place. The feature variable notation can be entirely eliminated since its one useful function is expressed by different means. The theory of feature geometry enables a simple hypothesis regarding the form of phonological rules, which radically constrains the power of phonological theory. This hypothesis is that phonological rules can perform one

simple operation (such as spreading, inserting or deletion) on a single element (a feature or organising node in the feature tree).

The thrust of much work on the organisation of phonological representations has been to show that this theory indeed predicts all and only the kinds of assimilations found in human languages (specific details of the structure of the feature tree have been refined so that we now know, for examples, that the features which characterise vowel height form a node in the feature tree, as do the features for the front/back distinction in vowels). The nonlinear account of assimilations precludes the unnatural classes constructed by the expressions in (99), since the theory has no way to tie a specific value for a feature to the value of another feature. The theory does not allow a rule like (97), which involve spreading of only some features under the place node. The nature of a tree like (88) dictates that when a rule operates on a higher node, all nodes underneath it are affected equally. Unattested 'assimilations' typified by (98) cannot be described at all in the feature geometric theory, since in that theory the concept 'assimilation' necessarily means 'of the same unit', which was not the case in the variable feature theory.

The theory of features in (88) makes other claims, pertaining to how place of articulation is specified, which has some interesting consequences. In the linear model of features, every segment had a complete set of plus or minus values for all features at all levels. This is not the case with the theory of (88). In this theory, a well-formed consonant simply requires specification of one of the **articulator nodes**, Labial, Coronal or Dorsal.[2] While a coronal consonant may have a specification under the Dorsal node for a secondary vocalic articulation such as palatalization or velarization, plain coronals will not have any specification for [back] or [high]; similarly, consonants have no specification for [round] or Labial unless they are labial consonants, or secondarily rounded. In other words, segments are specified in terms of positive, characteristic properties.

This has a significant implication in terms of natural classes. Whereas labials, coronals, and dorsals are natural classes in this theory, given that each has a common property — and in actual phonological processes, these segments do function as natural classes — the complement of these sets do not function as units in actual processes, and the theory in (88) provides no way to refer to the complement of those classes. Thus there is no natural class of [-coronal] segments in this theory, which would be the set [p,k] excluding [t,č]. Coronal is not seen as a binary feature in the theory, but is a single-valued or **privative** property, and thus there is no way to refer to the non-coronals since natural classes are defined in terms of properties which they share, not properties that they don't share (just as one would not class rocks and insects together as a natural group, to the exclusion of flowers, by terming the group 'the class of non-flowers'). Importantly, phonological rules do not ever seem to refer to the group [-coronal], even though the class [+coronal]

[2] Laryngeal consonants like *h* and *ʔ*, however, may lack any place specifications: the feature structure of laryngeals remains a topic for investigation.

is well attested as a phonological class. The model in (88) explains why we do not find languages referring to the set [p,k]. It also explains something that was unexplained in the earlier model: the consonantal groupings [p,t] versus [č,k] are unattested in phonological rules. The earlier model predicted these classes, which are based on assignment of the feature [±anterior]. In the model (88) the feature [anterior] is a dependent of the Coronal node, and thus labials and velars do not have a specification of [anterior], so there is no basis for grouping [p,t] or [č,k] together.

Exercises

1. Lulubo

Note on tone marks: [v̏̄] = rising tone from low to mid, [v̄̀] = falling tone from mid to low, [v̄́] = rising tone from mid to high and [v̄̂] = falling tone from high to mid. Give the underlying form of the noun roots and whatever morphemes mark the four case forms in the following data; briefly discuss what theoretically interesting property these data illustrate.

subject	*unfocused object*	*focused object*	*proper name object*	
èbì	ánḍɛ̀ èbì	ánḍɛ̀ èbǐ	ánḍɛ̀ èbī̏	'lion'
àrɪ̄	ánḍɛ̀ àrɪ̄̀	ánḍɛ̀ àrɪ̄́	ánḍɛ̀ àrɪ̄	'bird'
ṭ̤í	ánḍɛ̀ ṭ̤î	ánḍɛ̀ ṭ̤í	ánḍɛ̀ ṭ̤ī̂	'cow'

2: Holoholo

Verbs in this language are composed of an infinitive prefix or a subject marker, followed by an optional negative prefix, followed by an optional object pronoun, and lastly the verb stem. The verb stem is composed of a root, plus any number of optional derivational suffixes, plus the final morpheme -*a* which means "verb not in the past tense" or -*ile* meaning "past tense". There are a number of consonant mutation rules which can be ignored (eg. *il* → *in*), and some of the segmental allomorphs are rather obscure (some examples: *kuhuulééna* from /kuhuulilana/, or *kumweenâ* from /kumonila/). The details of how to get *kumweena* are not important: what is important is getting the correct tone. Focus on tonal rules and rules relating to vowel sequences. Assume a general principle of compensatory lengthening for this language whereby any rule of glide-formation or vowel fusion that applies to an underlying V+V sequence will lengthen the remaining vowel; therefore a gliding rule applying to /i+o/ will create [yoo], with lengthening of [o] being an automatic side-effect of glide formation.

There are some interesting regularities regarding vowel length that you should also consider. There are no surface representations such as *[kuponka] with a short vowel followed by the sequence nasal plus consonant. There are no forms like *[kufyaka] with short vowel after a glide. Furthermore, you will note that there are no words in the language that end in long vowel.

kumoná	to see	kusilá	to forge
kulola	to look at	kubula	to draw
kumonánâ	to see other	kusilílâ	to forge for
kulolana	to look at each other	kubulila	to draw for
kusilílána	to forge for each other	kubulilana	to draw for each other
kutegéléla	to listen	kutegélésya	to make listen
kutegélélana	to listen to each other	kusololana	to choose each other
kulyá	to eat	kuhyá	to carry
kuliilâ	to eat for	kuhiilâ	to carry for
kubuusyâ	to ask	kukwaatâ	to own
kubiihâ	to be bad	kuhiita	to be black
kutuuta	to hit	kusyiika	to bury
kuliilíla	to eat for for	kukwaatána	to own each other
kubiikâ	to put	kubiikílila	to put for
kumweenâ	to see for		
kusyiikana	to bury each other	kutuutila	to hit for
kwiitá	to call	kwiitánâ	to call each other
kweema	to suffer	kwaatíkâ	to split
kweelélâ	to clean up	kweelélána	to clean up each other
kwiihaga	to kill	kwiihagana	to kill each other
kooja	to rest	kuula	to buy
koogá	to wash	koogélâ	to wash for
koogéléla	to wash for for	koogélélana	to wash for each other
kutoontá	to fill	kutoontámána	to be full
kuloombá	to request	kuloombélâ	to request for
kuloombélána	to request for each other	kusiindálâ	to make disappear
kusiingínâ	to put across	kusiingínína	to put across for
kwiimbá	to sing	kwiimbílâ	to sing for
kunywiisâ	to make drink	kunywiisííbwa	to be made to drink
kuhuulééna	to hit for each other	kutimwíína	to break for
kuhimá	to leave	kuhimyâ	to make leave
kukwaatâ	to own	kukwaatyâ	to make own
koonká	to suck	koonkyâ	to make suck
kubusá	to miss	kubusyâ	to make miss
kukoloma	to irritate	kumukoloma	to irritate him
kubakólóma	to irritate them	kulola	to look at
kumulola	to look at him	kubalólâ	to look at them

kumumoná	to see him	kubamóná	to see them
kutegéléla	to listen to	kumutegéléla	to listen to him
kubatégéléla	to listen to them	kusimóná	to not see
kusilólâ	to not look at	kusikólóma	to not irritate
kusimúlóla	to not look at him	kusibálólâ	to not look at them
kusimúmóná	to not see him	kusibámóná	to not see them
kutiinína	to worry	kusitíínína	to not worry
kwiitíínína	to worry oneself	kumutiinína	to worry him
kwiilólâ	to look at oneself	kwiimóná	to see oneself
kuula	to buy	kusyuulâ	to not buy
kusyuulána	to not buy each other	kusimúúla	to not buy him
kwiitá	to call	kusiitá	to not call
kusiilólâ	to not look at oneself	kusiimóná	to not see oneself

ulolilé	you (sg) looked	usilílé	you (sg) forged
tulolilé	we looked	tusilílé	we forged
mulolilé	you (pl) looked	musilílé	you (pl) forged
úlólilé	he looked	úsílílé	he forged
bálólilé	they looked	básílílé	they forged