Introducing Phonology

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David Odden is Professor Emeritus in Linguistics at Ohio State University.
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Introducing Phonology

Second Edition

DAVID ODDEN
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This is an introductory textbook on phonological analysis, and does not assume any prior exposure to phonological concepts. The core of the book is intended to be used in a first course in phonology, and the chapters which focus specifically on analysis can easily be covered during a ten-week quarter. Insofar as it is a textbook in phonology, it is not a textbook in phonetics, and it presupposes an elementary knowledge of transcriptional symbols.

The main emphasis of this book is developing the foundational skills needed to analyze phonological data, especially systems of phonological alternations. For this reason, there is significantly less emphasis on presenting the various theoretical positions which phonologists have taken over the years. Theory cannot be entirely avoided, indeed it is impossible to state generalizations about a particular language without a theory which gives you a basis for postulating general rules. The very question of what the raw data are must be interpreted in the context of a theory, 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 that are discussed herein are chosen because they represent 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.
Acknowledgments

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Finally, I would like to acknowledge my debt to authors of various source books, in particular Whitley 1978, Halle and Clements 1983, Pickett 2002, and especially Kenstowicz and Kisseberth 1979.
A note on languages

The languages which provided data for this book are listed below. The name of the language is given, followed by the genetic affiliation and location of the language, finally the source of the data ("FN" indicates that the data come from my own field notes). Genetic affiliation typically gives the lowest level of the language tree which is likely to be widely known, so 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. 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 (or countries) is the primary location where the language is spoken, especially the particular dialect used; or this may be the country the language historically originates from (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).

Akan [Volta-Congo; Ghana]: Dolphyne 1988; Charles Marfo p.c.
Amharic [Semitic; Ethiopia]: Whitley 1978; Grover Hudson p.c.
Angas [Chadic; Nigeria]: FN.
Arabela [Zaparoan; Peru]: Rich 1963.
Aramaic (Azerbaijani) [Semitic; Azerbaijan]: Hoberman 1988.
Araucanian [Araucanian; Argentina, Chile]: Echeverría and Contreras 1965; Hayes 1995.
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 and p.c.
Bukusu [Bantu; Kenya]: Nsiombe Mutonyi p.c.
Cairene Arabic [Semitic; Egypt]: Broselow 1979.
Chukchi [Chukotko-Kamchatkan; Russia]: Krauss 1981.
Efik [Benue-Congo; Nigeria]: FN.
Evenki [Tungusic; Russia]: Konstantinova 1964; Nedjalkov 1997; Bulatova and Grenoble 1999.
Ewe (Anlo) [Volta-Congo; Benin]: Clements 1978.
Farsi [Indo-European; Iran]: Obolensky, Panah, and Nouri 1963.
Finnish [Uralic; Finland, Russia]: Whitney 1956; Lehtinen 1963; Anders Holmberg p.c.
Fore [Papuan; Papua New Guinea]: Pickett 2002.
Gà [Volta-Congo; Ghana]: FN in collaboration with Mary Paster.
Gen [Kwa; Togo]: FN.
Greek [Indo-European; Greece]: Georgios Tserdanelis p.c.
Guerze (Kpelle) [Mande; Guinea]: FN.
Hebrew [Semitic; Israel]: Kenstowicz and Kisseberth 1979.
Hehe [Bantu; Tanzania]: FN in collaboration with Mary Odden.
Holoholo [Bantu; Congo]: Coupez 1955.
Isthmus Zapotec [Oto-Manguean; Mexico]: Pickett 2002.
Jita [Bantu; Tanzania]: Downing 1996.
Kamba [Bantu; Kenya]: FN in collaboration with Ruth Roberts-Kohn.
Karok [Hokan; USA]: Bright 1957; Kenstowicz and Kisseberth 1979.
Keley-i [Austronesian; Philippines]: Kenstowicz and Kisseberth 1979; Lou Hohulin p.c.
Kenyang [Bantu; Cameroon]: FN.
Kera [Chadic; Chad]: Ebert 1975; Kenstowicz and Kisseberth 1979.
Kerewe [Bantu; Tanzania]: FN.
Kipsigis [Nilotic; Kenya]: FN.
Kolami [Dravidian; India]: Emeneau 1961.
Korean [Korean; Korea]: Martin 1992; Younghee Chung, Noju Kim, Mira Oh and Misun Seo p.c.
Koromfe [Gur; Burkina Fasso]: Rennison 1997.
Kotoko [Chadic; Cameroon]: FN.
Kuria [Bantu; Kenya]: FN.
Lardil [Pama-Nyungan; Australia]: Klokeid 1976.
Latin [Indo-European; Italy]: Allen and Greenough 1983; Hale and Buck 1966.
Lezgian [Northeast Caucasian; Dagestan and Azerbaijan]: Haspelmath 1993 and p.c.
Lithuanian [Indo-European; Lithuania]: Dambriunas, Klimas, and Schmalstieg 1966; Ambrazas 1997; Kenstowicz 1972a; Mathiassen 1996.
Liloogori [Bantu; Kenya]: FN in collaboration with Michael Marlo.
Luganda [Bantu; Uganda]: Cole 1967; Snoxall 1967.
Lulubo [Nilo-Saharan; Sudan]: Andersen 1987.
Makonde [Bantu; Mozambique]: Marcelino Liphola p.c.
Malay [Semitic; Malaysia]: Aquilina 1965; Borg and Azzopardi-Alexandre 1997; Brame 1972; Hume 1996.
Manipur [Sino-Tibetan; India, Myanmar, Bangladesh]: Bhat and Ningomba 1997.
Margyi [Chadic; Nigeria]: Hoffmann 1963.
Matuumbi [Bantu; Tanzania]: FN.
Mbunga [Bantu; Tanzania]: FN.
Mende [Mande; Liberia, Sierra Leone]: Leben 1978.
Mixtec [Mixtecan; Mexico]: Pike 1948; Goldsmith 1990a.
Mixteco [Oto-Manguean; Mexico]: Pickett 2002.
Mohawk [Hokan; USA]: Postal 1968; Beatty 1974; Michelson 1988 and p.c.
Mongo [Bantu; Congo]: Hulstaert 1961.
Mongolian [Altaic; Mongolia]: Hangin 1968.
Nkore [Bantu; Uganda]: FN in collaboration with Robert Poletto.
Norwegian [Germanic; Norway]: Ove Lorentz p.c.
Osage [Siouan; Oklahoma]: Gleason 1955.
Ossetic [Indo-European; Georgia, Russia]: Abaev 1964; Whitley 1978.
Palauan [Austronesian; Palau]: Josephs 1975; Flora 1974.
Polish [Slavic; Poland]: Kenstowicz and Kisseberth 1979.
Quechua (Cuzco) [Quechua; Peru]: Bills, Vallejo, and Troike 1969; Cusihuamán 1976.
Saami [Uralic; Sápmi (Norway, Sweden, Finland, Russia)]: FN in collaboration with Curt Rice and Berit Anne Bals Baal.
Sakha (Yakut) [Altaic; Russia]: Krueger 1962; Nadezhda Vinokurova p.c.
Samoan [Austronesian; Samoa]: Milner 1966.
Serbo-Croatian [Slavic; Yugoslavia]: Kenstowicz and Kisseberth 1979; Wayles Browne, Svetlana Godjevac, and Andrea Sims p.c.
Shambaa [Bantu; Tanzania]: FN.
Shona [Bantu; Zimbabwe]: FN.
Slave [Athapaskan; Canada]: Rice 1989.
Slovak [Slavic; Slovakia]: Kenstowicz 1972b; Rubach 1993.
Sundanese [Austronesian; Indonesia]: FN.
Swati [Bantu; Swaziland]: FN.
Syrian Arabic [Semitic; Syria]: Cowell 1964.
Tera [Chadic; Nigeria]: Newman 1968.
Thai [Tai; Thailand]: Halle and Clements 1983.
Tibetan [Sino-Tibetan; Tibet]: FN.
Tohono O’odham (Papago) [Uto-Aztecan; USA]: Saxton 1963; Saxton and Saxton 1969; Whitley 1978.
Tonkawa [Coahuiltecan; USA]: Hoijer 1933.
Tswana [Bantu; Botswana]: Cole 1955; Snyman, Shole, and Le Roux 1990.
Turkish [Altaic; Turkey]: Lees 1961; Foster 1969; Halle and Clements 1983.
Ukrainian (Sadžava, Standard) [Slavic; Ukraine]: Carlton 1971; Kenstowicz and Kisseberth 1979; Press and Pugh 1994 (Standard); Popova 1972 (Sadžava).
Urhobo [Edoid; Nigeria]: Aziza 2008 and p.c.; FN.
Vata [Kru; Côte d’Ivoire]: Kaye 1982.
Votic [Uralic; Russia]: Ariste 1968.

Wintu [Penutian; USA]: Pitkin 1984.
Woleaian [Austronesia; Micronesia]: Sohn 1975.
Xavante [Jé; Brazil]: Pickett 2002.
Yekhee (Etsako) [Edoid; Nigeria]: Elimelech 1978.
Yiddish [Germanic; Eastern Europe]: Neil Jacobs p.c.
Yoruba [Kwa; Nigeria]: Akinlabi 1984.
Zoque [Mixe-Zoquean; Mexico]: Pickett 2002.
**Abbreviations**

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Meaning</th>
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<tr>
<td>abl</td>
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<tr>
<td>acc</td>
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<td>ant</td>
<td>anterior</td>
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<td>ATR</td>
<td>advanced tongue root</td>
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<td>c.g.</td>
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<td>distr</td>
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<td>e.o.</td>
<td>each other</td>
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<td>ms(c)</td>
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<td>sg, sing</td>
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<td>s.g.</td>
<td>spread glottis</td>
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<td>sonorant</td>
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<td>sp</td>
<td>species</td>
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<td>1</td>
<td>first person</td>
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<td>3</td>
<td>third person</td>
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This chapter introduces phonology, the study of the sound systems of language. Its key objective is to:

- explain the difference between physical sound and “a sound” as a discrete element of language
- highlight the tradeoff between accuracy and usefulness in representing sound
- introduce the notion of “sound as cognitive symbol”
- present the phonetic underpinnings of phonology
- introduce the notion of phonological rule

**KEY TERMS**

- sound
- symbol
- transcription
- grammar
- continuous nature of speech
Phonology is one of the core fields that compose the discipline of linguistics, which is the scientific study of language structure. One way to understand the subject matter of phonology 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), word structure (morphology), or how languages change over time (historical linguistics). But this is insufficient. 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 phonology has a relationship to numerous 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. While phonetics and phonology both deal with language sound, they address different aspects of sound. Phonetics deals with “actual” physical sounds as they are manifested in human speech, and concentrates on acoustic waveforms, formant values, measurements of duration measured in milliseconds, of amplitude and frequency. Phonetics also deals with the physical principles underlying the production of sounds, namely vocal tract resonances, and the muscles and other articulatory structures used to produce those resonances. Phonology, on the other hand, is an abstract cognitive system dealing with rules in a mental grammar: 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 that you bring phonetics into consideration, just as a phonological analysis is a prerequisite for phonetic study of language.

1.1 Phonetics – the manifestation of language sound

Ashby and Maidment (2005) provide a detailed introduction to the subject area of phonetics, which you should read for greater detail on the acoustic and articulatory properties of language sounds, and transcription using the International Phonetic Alphabet (IPA). This section provides a basic overview of phonetics, to clarify what phonology is about.

From the phonetic perspective, “sound” refers to mechanical pressure waves and the sensations arising when such a pressure wave strikes your ear. In a physical sound, the wave changes continuously, and can be
graphed as a waveform showing the amplitude on the vertical axis and time on the horizontal axis. Figure 1 displays the waveform of a pronunciation of the word wall, with an expanded view of the details of the waveform at the center of the vowel between w and l.

Figure 2 provides an analogous waveform of a pronunciation of the word ‘will’, which differs from wall just in the choice of the vowel.

Inspection of the expanded view of the vowel part of these waveforms shows differences in the overall shape of the time-varying waveforms, which is what makes these words sound different.

It is difficult to characterize those physical differences from the waveform, but an analytical tool of phonetics, the spectrogram, provides a
useful way to describe the differences, by reducing the absolute amplitude properties of a wave at an exact time to a set of (less precise) amplitude characteristics in different frequency and time areas. In a spectrogram, the vertical axis represents frequency in Hertz (Hz) and darkness represents amplitude. Comparing the spectrograms of *wall* and *will* in figure 3, you can see that there are especially dark bands in the lower part of the spectrogram, and the frequency at which these bands occur – known as formants – is essential to physically distinguishing the vowels of these two words. Formants are numbered from the bottom up, so the first formant is at the very bottom.

In *wall* the first two formants are very close together and occur at 634 Hz and 895 Hz, whereas in *will* they are far apart, occurring at 464 Hz and 1766 Hz. The underlying reason for the difference in these sound qualities is that the tongue is in a different position during the articulation of these two vowels. In the case of the vowel of *wall*, the tongue is relatively low and retracted, and in the case of *will*, the tongue is relatively fronted and raised. These differences in the shape of the vocal tract result in different physical sounds coming out of the mouth.

The physical sound of a word’s pronunciation is highly variable, as we see when we compare the spectrograms of three pronunciations of *wall* in figure 4: the three spectrograms are obviously different.

The first two pronunciations are produced at different times by the same speaker, differing slightly in where the first two formants occur (634 Hz and 895 Hz for the first token versus 647 Hz and 873 Hz for the second), and in numerous other ways such as the greater amplitude of the lower formants in the first token. In the third token, produced by a second (male) speaker of the same dialect, the first two formants are noticeably lower and closer together, occurring at 541 Hz and 617 Hz.
Physical variation in sound also arises because of differences in surrounding context. Figure 5 gives spectrograms of the words wall, tall, and lawn, with grid lines to identify the portion of each spectrogram in the middle which corresponds to the vowel.

In wall, the frequency of the first two formants rapidly rises at the beginning and falls at the end; in tall, the formant frequencies start higher and fall slowly; in lawn, the formants rise slowly and do not fall at the end. A further important fact about physical sound is that it is continuous, so while wall, tall, and lawn are composed of three sounds where the middle sound in each word is the same one, there are no actual physical boundaries between the vowel and the surrounding consonants.

The tools of phonetic analysis can provide very detailed and precise information about the amplitude, frequency and time characteristics of an utterance – a typical spectrogram of a single-syllable word in English could contain around 100,000 bits of information. The problem is that this is too much information – a lot of information needs to be discarded to get at something more general and useful.

### 1.2 Phonology: the symbolic perspective on sound

Physical sound is too variable and contains too much information to allow us to make meaningful and general statements about the grammar of language sound. We require a way to represent just the essentials of language sounds, as mental objects which grammars can manipulate. A phonological representation of an utterance reduces this great mass of phonetic information to a cognitive minimum, namely a sequence of discrete segments.

#### 1.2.1 Symbolic representation of segments

The basic tool for converting the continuous stream of speech sound into discrete units is the phonetic transcription. The idea behind a transcription is that the variability and continuity of speech can be reduced to sequences of abstract symbols whose interpretation is predefined, a symbol standing for all of the concrete variants of the sound. Phonology then is the study of higher-level patterns of language sound, conceived in
terms of discrete mental symbols, whereas phonetics is the study of how those mental symbols are manifested as continuous muscular contractions and acoustic waveforms, or how such waveforms are perceived as the discrete symbols that the grammar acts on.

The idea of reducing an information-rich structure such as an acoustic waveform to a 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 possible speech sounds in human language. At a practical level, this assumption is embodied in systems of symbols and associated phonetic properties such as the International Phonetic Alphabet of figure 6. Ashby and Maidment (2005) give an extensive introduction to phonetic properties and corresponding IPA symbols, which you should consult for more information on phonetic characteristics of language sound.

The IPA chart is arranged to suit the needs of phonetic analysis. Standard phonological terminology and classification differ somewhat from this usage. Phonetic terminology describes [p] as a “plosive,” where that sound is phonologically termed a “stop”; the vowel [i] is called a “close” vowel in phonetics, but a “high” vowel in phonology. Figure 7 gives the important IPA vowel letters with their phonological descriptions, which are used to stand for the mental symbols of phonological analysis.

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

Three primary heights are generally recognized, namely high, mid, and low, augmented with the secondary distinction tense/lax for nonlow vowels which distinguishes vowel pairs such as [i] (seed) vs. [i] (Sid), [e] (late) vs. [e] (let), or [u] (food) vs. [u] (foot), where [i, e, u] are tense and [i, e, u] are lax. Tense vowels are higher and articulated further from the center of the vocal tract compared to their lax counterparts. It is not clear whether the tense/lax distinction extends to low vowels.

Independent of height, vowels can differ in relative frontness of the tongue. The vowel [i] is produced with a front tongue position, whereas [u] is produced with a 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 unrounded vowels.

With these independently controllable phonetic parameters – five degrees of height, three degrees of fronting, and rounding versus non-rounding – we have the potential for up to thirty vowels, which is
**THE INTERNATIONAL PHONETIC ALPHABET (revised to 2005)**

**CONSONANTS (PULMONIC)**

<table>
<thead>
<tr>
<th>Plosive</th>
<th>Bilabial</th>
<th>Labiodental</th>
<th>Dental</th>
<th>Alveolar</th>
<th>Postalveolar</th>
<th>Retroflex</th>
<th>Palatal</th>
<th>Velar</th>
<th>Uvular</th>
<th>Pharyngeal</th>
<th>Glottal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phonic</td>
<td>p b</td>
<td>t d</td>
<td>c j k q g</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nasal</td>
<td>m m̃</td>
<td>n ŋ j̃ ŋ̃ N</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trill</td>
<td>b</td>
<td>r</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tap or flap</td>
<td>ɾ ɽ</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fricative</td>
<td>ɸ β f v θ ð s z ʃ ʒ s z ç j x y χ š h ɦ h ɦ</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lateral approximant</td>
<td>ɻ ɻ</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Approximant</td>
<td>u ɹ ɹ ɹ ɹ ɹ ɹ ɹ ɹ</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Where symbols appear in pairs, the one to the right represents a voiced consonant. Shaded areas denote articulations judged impossible.

**CONSONANTS (NON-PULMONIC)**

<table>
<thead>
<tr>
<th>Clicks</th>
<th>Voiced implosives</th>
<th>Ejectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>O Bilabial</td>
<td>Bilabial</td>
<td>Examples: Bilabial</td>
</tr>
<tr>
<td>! Dental</td>
<td>Dental/alveolar</td>
<td>Dental/alveolar</td>
</tr>
<tr>
<td>(Port)alveolar</td>
<td>Palatal</td>
<td>Palatal</td>
</tr>
<tr>
<td>Alveolar</td>
<td>Velar</td>
<td>Velar</td>
</tr>
<tr>
<td>Alveolar lateral</td>
<td>Velar</td>
<td>Velar</td>
</tr>
</tbody>
</table>

**VOWELS**

Where symbols appear in pairs, the one to the right represents a rounded vowel.

**OTHER SYMBOLS**

- Voiceless labial-velar fricative: ɕ ʑ Alveolo-palatal fricatives
- Voiced labial-velar approximant: ɻ ɻ Voiced alveolar lateral flap
- Voiced labial-palatal approximant: ɬ ɬ Simultaneous ʃ and x
- Voiceless epiglottal fricative: ɭ ɭ
- Voiceless epiglottal fricative: ɭ ɭ
- Epiglottal fricative: ɭ ɭ

**DIACRITICS**

- Voiceless n ɾ d ɽ Breathe voiced b ɹ a Dental t d
- Voiced s ɾ t ɽ Cranky voiced b ɹ a Apical t d
- Aspirated tʰ ɽʰ Lhingoalabial ɽdh ɽd Laminal ɽd
- More rounded ɾ E Labialized t ɽ d ɽ Nasal ɽd
- Less rounded ɹ Palaized ɹ ɽ d ɽ Nasal release ɽd
- Advanced ɹ Velarized ɹ ɽ d ɽ Lateral release ɽd
- Retracted ɭ ɭ Pharyngalized ɭ ɭ No audible release ɭd
- Centralized ɭ Velarized or pharyngalized ɭ
- Mid-centralized ɭ Raised ɭ (ɭ = voiced alveolar fricative)
- Syllabic ɹ Lowered ɹ (ɹ = voiced bilabial approximant)
- Non-syllabic ɭ Advanced Tongue Root ɭ
- Rhoticity ʃ ɹ a Retracted Tongue Root ɭ

**SUPRASEGMENTALS**

- Primary stress
- Secondary stress
- Long ɹoun ɹən
- Half-long ɹe ɹe
- Extra-short ɹe ɹe
- Minor (foot) group
- Major (intonation) group
- Syllable break ɹəkt
- Linking (absence of a break)

**TONES AND WORD ACCENTS**

- Extra high ɹə or ɭ Rising
- High ɹə or ɭ Falling
- Mid ɹə or ɭ High rising
- Low ɹə or ɭ Low rising
- Extra low ɹə or ɭ Rising-falling
- Downstep ɹə or ɭ Global rise
- Upright ɹə or ɭ Global fall
many more vowels than are found in English. Many of these vowels are lacking in English, but can be found in other languages. This yields a fairly symmetrical system of symbols and articulatory classifications, but there are gaps such as the lack of tense/lax distinctions among central high vowels.

The major consonants and their classificatory analysis are given in figure 8.

Where the IPA term for consonants like [p b] is “plosive,” these are referred to phonologically as “stops.” Lateral and rhotic consonants are termed “liquids,” and non-lateral “approximants” are referred to as “glides.” Terminology referring to the symbols for implosives, ejectives, diacritics, and suprasegmentals is generally the same in phonological and phonetic usage.

Other classificatory terminology is used in phonological analysis to refer to the fact that certain sets of sounds act together for grammatical purposes. Plain stops and affricates are grouped together, by considering affricates to be a kind of stop (one with a special fricative-type release). Fricatives and stops commonly act as a group, and are termed obstruents, while glides, liquids, nasals, and vowels likewise act together, being termed sonorants.

1.2.2 The 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 but are not the same as physical sounds.

The sounds of a language. One aspect of phonology investigates what the “sounds” of a language are. We would want to take note in a description of the phonology of English that we lack the vowel [ø] 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 [Ø] exists in English (spelled th in thing, path), as well as Icelandic, Modern Greek, and North Saami), but not in German or French,
and not in Latin American Spanish (but it does occur in Continental Spanish in words such as *cerveza* ‘beer’).

Sounds in languages are not just isolated atoms; they are part of a system. The systems of stops in Hindi and English are given in (1).

(1) Hindi stops

<table>
<thead>
<tr>
<th>p</th>
<th>t</th>
<th>ṭ</th>
<th>k</th>
</tr>
</thead>
<tbody>
<tr>
<td>ṃ</td>
<td>ṇ</td>
<td>ḋ</td>
<td>ḍ</td>
</tr>
<tr>
<td>b</td>
<td>d</td>
<td>ḍ</td>
<td>g</td>
</tr>
</tbody>
</table>

English stops

<table>
<thead>
<tr>
<th>p</th>
<th>t</th>
<th>ṭ</th>
<th>k</th>
</tr>
</thead>
<tbody>
<tr>
<td>ṃ</td>
<td>ṇ</td>
<td>ḋ</td>
<td>ḍ</td>
</tr>
<tr>
<td>b</td>
<td>d</td>
<td>ḍ</td>
<td>g</td>
</tr>
</tbody>
</table>

The stop systems of these languages differ in three ways. English does not have a series of voiced aspirated stops like Hindi [ph ṭh dh ḍḥ gh], nor does it have a series of retroflex stops [ʈʈ h ḍɖ]. Furthermore, the phonological status of the aspirated sounds [ph ṭh kh] is different in the languages, as discussed in chapter 2, in that they are basic lexical facts of words in Hindi, but are the result of applying a rule in English.

Rules for combining sounds. Another aspect of language sound which a phonological analysis takes account of is that in any language, certain combinations of sounds are allowed, but other combinations are systematically impossible. The fact that English has the words [bɹɪk] *brick*, [bɹɛk] *break*, [bɹɪdʒ] *bridge*, [bɹɛd] *bread* is a clear indication that there is no restriction against having words that 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 [bluː] *blue*, [bleʔn] *blatant*, [blaːst] *blast*, [blend] *blend*, [bliŋk] *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 nonexistence of this word is simply that it is an accidental gap – 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 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. Sixty years ago the English language did not have any word pronounced [bk], 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 have that word – spelled *Bic* – which is the brand name of a ballpoint pen.

While the nonexistence of *blick* in English is accidental, the exclusion from English of many other imaginable but nonexistent words is based on

¹ The asterisk is used to indicate that a given word is nonexistent or wrong.
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 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 *pnum, *pnig, *pnilge, but also by the fact that the word spelled pneumonia which derives from Ancient Greek (a language which does allow such consonant combinations) is pronounced [nʌˈmənɪə] without p. A description of the phonology of English would provide a basis for characterizing 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 [iz], represented in spelling as es, when the preceding consonant is one of a certain set of consonants including [ʃ] (spelled sh) as in bushes, [tʃ] (spelled as ch) as in churches, and [dʒ] (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 s² 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 represents physical sounds. What phonology is concerned with is how sounds behave in a grammar.

---

**Summary**

Phonetics and phonology both study language sound. Phonology examines language sounds as mental units, encapsulated symbolically for example as [æ] or [ɡ], and focuses on how these units function in grammars. Phonetics examines how symbolic sound is manifested as a continuous physical phenomenon. The conversion from the continuous external domain to mental 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 discover exactly what these cognitively important properties are, and how they function in expressing regularities about languages.

---

² This is the “apostrophe s” suffix found in the child’s shoe, meaning ‘the shoe owned by the child.’
Exercises

The first three 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. Why would it be undesirable to use the most precise representation of the physical properties of a spoken word that can be created under current technology in discussing rules of phonology?

The following five questions focus on technical skills.

4. How many segments (not letters) are there in the following words (in actual pronunciation)?
   sit judge trap fish bite ball up ox through often

5. Give the phonetic symbols for the following segments:
   - voiced velar fricative
   - voiceless velarized alveolar affricate
   - interdental nasal
   - ejective uvular stop
   - low front round vowel
   - back mid unrounded vowel
   - lax back high round vowel
   - voiced palatal fricative
   - syllabic bilabial nasal
   - voiced laryngeal fricative
   - voiceless rounded pharyngeal fricative
   - palatalized voiceless alveolar stop

6. From the following pairs of symbols, select the symbol which matches the articulatory description.
   - e ɛ front mid lax vowel
   - ü û creaky high rounded vowel
   - x χ voiced velar fricative
   - i ɨ lax front high vowel
   - ɬ ʔ glottal stop
   - θ ɺ dental affricate
   - ʒ ʝ alveopalatal fricative
   - ʝ ɥ labio-palatal glide
7. Provide the articulatory description of the following segments. Example:

\[ \theta \quad \text{voiceless interdental fricative} \]

\[ \alpha \quad \text{a} \]
\[ \eta \quad \text{g} \]
\[ \upsilon \quad \text{y} \]
\[ \alpha e \quad \text{ø} \]
\[ t^\text{\textdegree} \quad \text{s} \]
\[ j \quad \text{k} \]
\[ x \quad \text{i} \]
\[ b^v \quad g^w \]
\[ g^v \quad ? \]

8. Name the property shared by each segment in the following sets:

\[ \text{r s z n d t b j l} \]
\[ \text{g k} \]
\[ \text{a a ai æ w y i e} \]
\[ \text{j n j} \]
\[ \text{i o e o} \]
\[ \text{u u y} \]

---

**Further reading**

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

- learn of predictable variants of basic sounds in English
- learn about the concepts “phoneme” and “allophone”
- discover that similar relations between sounds exist in other languages
- begin to learn the general technique for inducing phonological rules from data that come from a language which you do not know
- be introduced to writing phonological rules
As explained in the preceding chapter, the focus of phonology is 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, a list of words (or morphemes – parts of words), which must provide any information which cannot be predicted by rules of the language. However, much about the pronunciation of words can be predicted. For example, in the word *tick* the initial voiceless consonant *t* is phonetically aspirated, and is phonetically [θɪk]. This aspiration can be demonstrated visually by dangling a tissue in front of the mouth when saying the word: notice that when you pronounce *t*, the tissue is blown forward. In comparison, *t* in the word *stick* is not aspirated (thus, the tissue is not blown forward), so this word is transcribed as [stɪk]. This fact can be predicted by rule, and we now consider how this is done.

### 2.1 English consonantal allophones

While the physical difference between *t* and *tʰ* in English is just as real as the difference between *t* and *d*, there is a fundamental linguistic difference between these two relationships. 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)  
<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>[d]</td>
<td>[t]</td>
<td>[d]</td>
<td>[t]</td>
</tr>
<tr>
<td>dire</td>
<td>tire</td>
<td>do</td>
<td>two</td>
</tr>
<tr>
<td>Dick</td>
<td>tick</td>
<td>had</td>
<td>hat</td>
</tr>
<tr>
<td>said</td>
<td>set</td>
<td>bend</td>
<td>bent</td>
</tr>
</tbody>
</table>

The difference between [t] and [d] is **contrastive** (also termed **distinctive**) in English, since this difference – voicing – forms the sole basis for distinguishing different words (and thus, [t] and [d] contrast).

The choice of a voiceless aspirated stop such as [tʰ] versus a voiceless unaspirated stop such as [t], on the other hand, never defines the sole basis for differentiating words in English. The occurrence of [t] versus [tʰ] (also [k] versus [kʰ], and [p] versus [pʰ]) 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 [tʰ] are predictable variants of a single abstract segment, a **phoneme**, which we represent as /t/. Purely 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 pronounced segments and the abstract mental constructs that they derive from, the phonemes, which represent the unity behind
observed [t] and [tʰ] etc. The implicit claim is that despite there being actual differences, [t] and [tʰ] (also [k] and [kʰ], [p] and [pʰ]) are in a fundamental sense “the same thing.” We reduce the output sounds [t tʰ k kʰ p pʰ] to just the set of sounds /t k p/, and a rule provides the information “realized as [t] vs. [tʰ]” to account for these regularities.

### 2.1.1 Aspiration

We will turn our attention to 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**

<table>
<thead>
<tr>
<th>pool</th>
<th>[pʰuwl]</th>
<th>tooth</th>
<th>[tʰuwl]</th>
<th>coop</th>
<th>[kʰuwp]</th>
</tr>
</thead>
<tbody>
<tr>
<td>pit</td>
<td>[pʰt]</td>
<td>tin</td>
<td>[tʰin]</td>
<td>kill</td>
<td>[kʰil]</td>
</tr>
<tr>
<td>apply</td>
<td>[sʰpʰlaj]</td>
<td>atomic</td>
<td>[sʰtʰamik]</td>
<td>account</td>
<td>[sʰkʰæwnt]</td>
</tr>
<tr>
<td>prawn</td>
<td>[pʰsʰlan]</td>
<td>truth</td>
<td>[tʰuwl]</td>
<td>crab</td>
<td>[kʰræb]</td>
</tr>
<tr>
<td>pueblo</td>
<td>[pʰwʰblow]</td>
<td>twine</td>
<td>[tʰwajn]</td>
<td>quill</td>
<td>[kʰwël]</td>
</tr>
<tr>
<td>play</td>
<td>[pʰlej]</td>
<td>clay</td>
<td>[kʰlej]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>puce</td>
<td>[pʰjuws]</td>
<td>cube</td>
<td>[kʰjuws]</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(3) **Unaspirated stops**

| spool     | [sʰptǔwl] | stool  | [stuwl] | school     | [sʰkʰuwl] |
| spit      | [sʰpʰit]  | stick  | [stik]  | skid       | [sʰkʰid]  |
| sap       | [sʰæp]   | sat    | [sʰæt]  | sack       | [sʰæk]   |
| spray     | [sʰpʰlej] | stray  | [sʰtʰlej] | screw      | [sʰkʰuwl] |
| split     | [sʰpʰlt]  | sclerosis | [sʰkʰlərəsʰsɪ] |
| spew      | [sʰpʰwʰ]  | skew   | [sʰkʰwʰ] |

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 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, only 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 detail 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.

(4) ˈhæpi ˈkæmpɪŋ ˈhelplɪŋ
ˈlʌki ˈslʌkɪ ˈsaltɪŋ

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

(5) voiceless stop → aspirated /ˈs__

This statement introduces the method of writing rules, which will be used in the book. Rules generally take the form “A→B/C_D,” where A, C, D are variables that stand for single segments like [l] or [d] or phonetic classes such as “voiceless stop,” and B describes the nature of the change, some phonetic parameter such as “voiceless” or “nasal.” The conditioning context might involve only a preceding element in which case “D” would be missing, it might involve only a following element in which case “C” would be missing, or the applicability of the rule might depend on both what precedes and what follows. The arrow means “becomes,” the slash means “in the environment” where the context is what follows the slash. The notation “ˈs__” means “beginning of a stressed syllable,” thus “voiceless stops become aspirated when they are preceded by the beginning of a stressed syllable.” The final chapter of the book introduces syllables in more detail.

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

(6) [əˈplæj] apply [əˈplækˈeɪʃn] application
[əˈpləʊz] suppose [əˈspəʊzən] supposition
[əˈkwər] acquire [əˈkwərəzən] acquisition
As predicted by our rule for aspiration, the phonetic presence or absence of aspiration on the medial stop of the root may alternate within a given root, according to where the stress appears in the root.

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

(7) Verb Subject noun Object noun
[ɡænt] [ɡæntɪ] [ɡæntʰɪ] grant
[ʃɪft] [ʃɪftɪ] [ʃɪftʰɪ] shift
[ˈhelp] [ˈhelpɪ] [ˈhelpʰɪ] help
[θəʊk] [θəʊkɪ] [θəʊkʰɪ] choke
[stəɪk] [stəɪkɪ] [stəɪkʰɪ] strike
[əˈθæk] [əˈθækɪ] [əˈθækʰɪ] 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 [ˈstɔrd] and [ˈpɔlma], as predicted by the aspiration rule. The name Stavanger (Norway) may be pronounced many ways – [stʌˈværŋ], [stʌvænɡ], [stɑːˈværŋ], [ˈstæværŋ], and so on, but consistently throughout this variation, the /t/ will remain unaspirated because of its position in the syllable. In the English pronunciation of Rapallo (Italy), stress could either be on the first syllable in [ˈræpələʊ], with no aspiration because /p/ is at the beginning of an unstressed syllable, or on the second syllable as in [ˈræ pʰələʊ] – 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 [pʰɔl] ‘fruit’ and [stɑː] ‘breast’ are not difficult for English speakers to pronounce; accurate pronunciation of [pʰɑl] ‘want’ and [stʰɑl] ‘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* [ˈhæpi], only the first syllable is stressed and therefore [p] remains unaspirated. However, if this word is pronounced very slowly, drawing out each vowel, then both syllables become stressed, and as predicted the stop *p* is aspirated – [ˈhæ::]...[ˌˌphi::]. All of these facts are explained by one simple hypothesis, that in English the occurrence of aspiration on stops derives from applying a rule.

2.1.2 Flapping

We now turn to another rule. A phonetic characteristic of many North American dialects of English is “flapping,” where /t/ and /d/ become the flap [ɾ] in certain contexts, for example in [ˈwaɾɹ̩] *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 “[bʌt] and [bʌɾ], whose existence would establish that the flap is a distinct phoneme of English. Moreover, the contexts where the flap appears in English are quite restricted. In our previous examples of nonaspiration in the context ˈV_Cv in (4) and (6), no examples included [t] as an intervocalic consonant. Now consider the following words:

(8) a. ˈwaɾɹ̩ water ˈweɾɹ̩ waiter; wader
ˈæɾɹ̩ atom; Adam ˈæɾɹ̩ˌθ̩uwð attitude

b. ˈhɪt hit ˈhɪɾɹ̩ hitting
ˈpʊt put ˈpʊɾɹ̩ putting
ˈsɛt set ˈsɛɾɹ̩ setting

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

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

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

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

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

(10) Base verbs ‘One who V-s’ ‘V-ing’

<table>
<thead>
<tr>
<th>verb</th>
<th>‘verb’</th>
<th>‘verb’</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘bid’</td>
<td>’bɪɾɪ</td>
<td>’bɪɾɪŋ</td>
</tr>
<tr>
<td>‘hajd’</td>
<td>’hɑjɾɪ</td>
<td>’hɑjɾɪŋ</td>
</tr>
<tr>
<td>‘wejd’</td>
<td>’wɛjɾɪ</td>
<td>’wɛjɾɪŋ</td>
</tr>
</tbody>
</table>

2.1.3 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 [n]. Consider, first, examples such as [ˈbɑʔn] button and [ˈkaʔn] 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 [n]. Consider the following pairs of words:

(11) [rat] rot | [ˈraʔn] rotten
[haɪt] height | [ˈhɑʔn] heighten
[laɪt] light | [ˈlɑʔn] lighten
[faɪt] fat | [ˈfæʔn] fatten

The bare roots on the left show the underlying /t/ which has not changed to glottal stop, and on the right, we observe that the addition of the suffix /n/ conditions the change of /t/ to [ʔ] in the context ‘V_n, i.e. when t is preceded by a stressed vowel and followed by an alveolar nasal. Words like [ˈɑʔm] 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 -ŋ may be pronounced as [n]. When the verb root ends in /t/, that /t/ becomes [ʔ] just in case the suffix becomes [ŋ], and thus provides the crucial context required for the glottal stop creation rule.
In the examples considered so far, the environment for appearance of glottal stop has been a following syllabic [n]. Is it crucial that the triggering nasal segment be specifically a syllabic nasal? We also find glottal stop before non-syllabic nasals in words such as Whitney [ʍɪʔnɪʔ] and fatness [fæʔnə()], which shows that the t-glottalization rule does not care about the syllabicity of the following nasal. The presence of glottal stop in these examples can be explained by the existence of a rule which turns /t/ into glottal stop before [n] or [n̩].

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

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

### 2.2 Allophony in other languages

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

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

(14) lɛfifi ‘darkness’ loleme ‘tongue’
sɛlɛpɛ ‘axe’ molomo ‘mouth’
xɔbalɔ ‘to read’ mmadi ‘reader’
lerumɔ ‘spear’ xoqala ‘to marry’
loxadima ‘lightning flash’ didɔ ‘food’
dumɔla ‘greetings’ feedi ‘sweeper’
lokwalɔ ‘letter’ kʰudu ‘tortoise’
mosadi ‘woman’ podi ‘goat’
badisɔ ‘the herd’ hudi ‘wild duck’
Tswana has a rule which can be stated as “/l/ becomes [d] before high vowels.”

(15)  \( l \rightarrow d \_ \text{high vowel} \)

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

(16)  \( d \rightarrow l \_ \text{nonhigh vowel} \)

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

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

(17)  \( \text{d}^{\text{ihsk}} \quad \text{‘aunt’} \quad \text{d}^{\text{ʔaʔk}} \quad \text{‘mountain’} \)
    \( \text{t}^{\text{uʔi}} \quad \text{‘corner’} \quad \text{t}^{\text{uwaʔgi}} \quad \text{‘clouds’} \)
    \( \text{wahtfum} \quad \text{‘drown’} \quad \text{taht} \quad \text{‘foot’} \)
    \( \text{d}^{\text{uwuʔkoh}} \quad \text{‘cut hair’} \quad \text{ʔahidaʔk} \quad \text{‘year’} \)
    \( \text{t}^{\text{nəm}} \quad \text{‘be thirsty’} \quad \text{huhtahpsptʃu} \quad \text{‘make it 5’} \)
    \( \text{huŋtʃu} \quad \text{‘self’} \quad \text{t}^{\text{hikpaŋ}} \quad \text{‘work’} \)
    \( \text{stahtɔnɔmʔah} \quad \text{‘thirsty times’} \quad \text{ʔi:d} \quad \text{‘this’} \)
    \( \text{muʔudəm} \quad \text{‘runner’} \quad \text{t}^{\text{hnətʃ} \quad \text{‘degenerate’}} \)
    \( \text{tɔdsid} \quad \text{‘frighten’} \quad \text{t}^{\text{upɔsid}} \quad \text{‘brand’} \)
    \( \text{gahtwi} \quad \text{‘to shoot’} \quad \text{t}^{\text{uhtʃi}} \quad \text{‘name’} \)
    \( \text{ɡuʔudtə} \quad \text{‘get big’} \quad \text{d}^{\text{umali}} \quad \text{‘low’} \)
    \( \text{tɔbidk} \quad \text{‘White Clay’} \quad \text{waʔd}^{\text{iwih}} \quad \text{‘swim’} \)
    \( \text{spadmahkəm} \quad \text{‘lazy one’} \quad \text{d}^{\text{uʔw}} \quad \text{‘rabbits’} \)

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

Let us start with the hypothesis that it is the immediately preceding segment which determines how the consonant is pronounced. In order to organize the data so as to reveal what rule might be at work, we can
simply list the preceding environments where stops versus affricates appear, so \( h \) means “when \([h]\) precedes” – here, the symbol “\#” represents the beginning or end of a word. Looking at the examples in (17), and taking note of what comes immediately before any \([t, d]\) versus \([t^\#, d^\#]\), we arrive at the following list of contexts:

\[
(18) \quad [t, d]: \#., h., \text{i:}., s., n., \text{s}. \\
[t^\#, d^\#]: \#., h., \text{w}. , \text{ʔ}. , \text{p}.
\]

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

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

\[
(19) \quad [t, d]: \_\text{ɔ}, \_\text{a}, \_\text{ə}, \_\#, \_\text{s}, \_\text{t}, \_\text{k}, \_\text{u}, \_\text{w} \\
[t^\#, d^\#]: \_\text{i}, \_\text{ɪ}, \_\text{u}, \_\text{u}, \_\text{w}
\]

Only the vowels \([i, u, \text{u}]\) (and their devoiced counterparts) follow \([t^\#]\) and \([d^\#]\), and the vowels \([a, ə]\) 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 (\(\text{taht, txdsid}\)). The vowels \([i, u, \text{u}]\) have in common the property that they are high vowels, which allows us to state the context for this rule very simply: /t/ and /d/ become alveopalatal affricates before high vowels, i.e.

\[(20) \quad \text{alveolar stop} \rightarrow \text{alveopalatal affricate} / \_\text{high vowel}\]

The retroflex consonant \([d]\) does not undergo this process, as seen in \([\text{muqudam}].\)

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

\[
(21) \quad \text{alveopalatal affricate} \rightarrow \text{alveolar stop} / \_\left\{ \begin{array}{l} \text{nonhigh V} \\
\text{C} \\
\# \end{array} \right\}
\]

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

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

(22) θok-ta ‘dog’  θog-iik ‘dogs’
ke-tcp ‘request’  i-teb-e ‘you are requesting’
ker ‘look at!’  ke-ger ‘to look at’
put ‘break up!’  ke-but ‘to break up’
poor ‘thresh maize!’  ke-boor ‘to thresh maize’
ŋeljep-ta ‘tongue’  ŋeljeb-tek ‘tongues’
kisipti ‘to follow for’  ingurwet ‘pig’
kipkirui (name)  ke-baakpaak ‘to strip repeatedly’
ponbon ‘soft’  tilakse ‘it is cuttable’
kirgit ‘bull’  kagjam ‘we ate’
taaptaet ‘flower type’  kebritamaet ‘to fall asleep’
kiblajat (name)  peettle ‘they are going for themselves’

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

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

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

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

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

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

(24) ɓẹɓέlə ‘male goat’ ɠündumuka ‘be scared’
ɓụtuka ‘flow’ ɡàala ‘storage in roof’
koɓọkwə ‘unfold’ ɓwọm ‘life’
koŋndwa ‘dig clay’ ɡaambaŋ ‘fish (sp)’
ɓalaŋa ‘luck’ ɡoloja ‘drive fast’
liseɛŋgɛlɛ ‘dowry’ ɓila ‘without’
ɡbìlɔ ‘straighten’ ɓuna ‘murmur’
kiɓula ‘towards Mecca’ kitɔmb ‘hill’
kjaŋgi ‘sand’ ɓɔmwaana ‘destroy’
lıkɔɔŋgwa ‘storage structure’ ɓɔoka ‘leave’
ɡɔɔmba ‘shoot a gun’ ɡoloka ‘fly’
ɓalaangga ‘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 -ε in the “should” form, the second column below).
Thus the pronunciation of the root for the word for ‘fly’ alternates between \[ɠʊʟʊk\] and \[gʊʟʊk\], depending on whether a nasal precedes.

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

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

(26) \[C \rightarrow \text{implosive} / \left\{ \begin{array}{c} V \\ # \end{array} \right\} -\]

versus “plain consonants appear after a nasal”:

(27) \[C \rightarrow \text{nonimplosive} / \text{nasal}_-\]

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

It is worth noting that another statement of the implosive-to-plain process is possible, since sequences of consonants are quite restricted in Matuumbi. Only a nasal may precede another “true” consonant, i.e. a consonant other than a glide. A different statement of the rule is that plain voiced consonants appear only after other consonants – due to the rules of 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 data set, so we must accept that there are at least two ways of describing this pattern. One of the goals of the theory, towards which considerable research energy is being expended, is developing a principled basis for making a unique and correct choice in such cases where the data themselves cannot show which solution is right.

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

\[
\begin{align*}
(28) & \quad \text{en}q & \quad \text{‘tree’} & \quad \text{en}q & \quad \text{‘drum’} \\
& \quad \text{eket} & \quad \text{‘house’} & \quad \text{nti}k\text{u} & \quad \text{‘I am buying’} \\
& \quad \text{nek} & \quad \text{‘rope’} & \quad \text{ejwarek} & \quad \text{‘sweet potato’} \\
& \quad \text{ngaoq} & \quad \text{‘knife’} & \quad \text{ekaoq} & \quad \text{‘leg’} \\
& \quad \text{moq} & \quad \text{‘dirt’} & \quad \text{naq} & \quad \text{‘brother in law’} \\
& \quad \text{nde}k & \quad \text{‘European’} & \quad \text{pobrik} & \quad \text{‘work project’} \\
& \quad \text{bet}oq & \quad \text{‘job’} & \quad \text{be}p\text{a}k & \quad \text{‘to capsize’} \\
& \quad \text{ti}k\text{u} & \quad \text{(name)} & \quad \text{ku} & \quad \text{‘buy!’} \\
& \quad \text{ajuk} & \quad \text{(name)} & \quad \text{esik\text{qj}} & \quad \text{‘pipe’} \\
& \quad \text{kebwep} & \quad \text{‘stammering’} & \quad \eta k\text{aoq} & \quad \text{‘chicken’} \\
& \quad \eta k\text{ap} & \quad \text{‘money’} & \quad \text{ko} & \quad \text{‘walk!’}
\end{align*}
\]

What determines the selection of \( k \) versus \( q \) is the nature of the vowel which precedes the consonant. The uvular consonant \( q \) is always preceded by one of the back nonhigh vowels \( o, \dot{o}, \text{ or } a \), whereas velar \( k \) appears anywhere else.

\[
(29) \quad \text{voiceless velar} \rightarrow \text{uvular / back nonhigh vowel}
\]

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 (\( \eta \)), or by a word boundary. We would then end up with a disjunction of contexts in our statement of the rule.

\[
(30) \quad q \rightarrow k / \begin{cases}
\text{front \text{V}} \\
\text{central \text{V}} \\
\text{high back \text{V}}
\end{cases} #
\]


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

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

(31)  
<table>
<thead>
<tr>
<th>Arabela</th>
<th>English</th>
</tr>
</thead>
<tbody>
<tr>
<td>nëčkjæ?</td>
<td>‘lying on back’</td>
</tr>
<tr>
<td>tukuru?</td>
<td>‘palm leaf’</td>
</tr>
<tr>
<td>njačëri?</td>
<td>‘he laid it down’</td>
</tr>
<tr>
<td>niičkjæ?</td>
<td>‘is pouring out’</td>
</tr>
<tr>
<td>posunähä?</td>
<td>‘short person’</td>
</tr>
<tr>
<td>nõönü?</td>
<td>‘be pained’</td>
</tr>
<tr>
<td>tæwe?</td>
<td>‘foreigner’</td>
</tr>
<tr>
<td>nínjü?</td>
<td>‘to come’</td>
</tr>
<tr>
<td>nũwũ?</td>
<td>‘partridge’</td>
</tr>
<tr>
<td>mõnû?</td>
<td>‘kill’</td>
</tr>
<tr>
<td>ūjokwa?</td>
<td>‘grease’</td>
</tr>
<tr>
<td>suro?</td>
<td>‘monkey’</td>
</tr>
<tr>
<td>suwaka?</td>
<td>‘fish’</td>
</tr>
<tr>
<td>kuwoxo?</td>
<td>‘hole’</td>
</tr>
<tr>
<td>hēëgi?</td>
<td>‘termites’</td>
</tr>
<tr>
<td>ħjǔūjjaenö?</td>
<td>‘where I fished’</td>
</tr>
<tr>
<td>mjäenũ?</td>
<td>‘swallow’</td>
</tr>
<tr>
<td>hũũwũ?</td>
<td>‘a yellow bird’</td>
</tr>
</tbody>
</table>

Scanning the data in (31), we see nothing about the following phonetic context that explains occurrence of nasalization: both oral and nasal vowels precede glottal stop ([tæwe?] ‘foreigner’ versus [nõönũ?] ‘be pained’), [k] ([niičkjæ?] ‘is pouring out’ versus [ūjokwa?] ‘grease’) or [n] ([mjäenũ?] ‘swallow’ versus [posunähä?] ‘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 [ŋ] which is always nasal in this language), vowel, or glide – then a vowel or glide becomes nasalized. The rule for nasalization can be stated as “a vowel or glide becomes nasalized after any nasal sound.”

(32)  
\[ \text{vocoid} \rightarrow \text{nasal / nasal}_- \]

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

**Sundanese: a problem for the student to solve.** Bearing this suggestion in mind, where do nasalized vowels appear in Sundanese (Indonesia), given these data?
Since the focus at the moment is on finding phonological regularities, and not on manipulating a particular formalism (which we have not yet presented completely), you should concentrate on expressing the generalization in clear English.

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

What rule determines the length of consonants in this language?

**Vowel length in Mohawk.** The context for predicting some variant of a phoneme may include more than one factor. There is no contrast between long and short vowels in Mohawk (North America): what is the generalization regarding where long versus short vowels appear?
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 \(ˈ\text{wisk}\). We must find a further property which distinguishes those stressed vowels which become lengthened from those which do not. Looking only at stressed vowels, we can see that short vowels appear before two consonants and long vowels appear before a consonant-plus-vowel sequence. It is the combination of two factors, being stressed and being before the sequence CV, which conditions the appearance of long vowels: stressed vowels are lengthened if they precede CV, and vowels remain short otherwise. We hypothesize the following rule:

(36) \(\text{stressed V} \rightarrow \text{long /}_\text{CV}\)

Since there is no lexical contrast between long and short vowels in Mohawk, we assume that all vowels have the same underlying length: all long and shortened in one context, or all short and lengthened in the complementary context. One hypothesis about underlying forms in a given language results in simpler grammars which capture generalizations about the language more directly than do other hypotheses about underlying forms. If all vowels in Mohawk are underingly long, you must devise a rule to derive short vowels. No single generalization covers all contexts where supposed vowel shortening takes place, so your analysis would require two rules, one to shorten unstressed vowels, and another to shorten vowels followed by two consonants. In comparison, the single rule that stressed vowels lengthen before CV accounts for vowel length under the hypothesis that vowels in Mohawk are underingly 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 (Caucasus).

(37)  
\[\text{t}^{\text{h}}\text{γ}_\chi\] ‘strength’  \[\text{k}^{\text{h}}\text{стаг} \] ‘linen’  
\[\gamma\text{ство} \] ‘near’  \[\text{стон} \] ‘be added’  
\[\text{fadат}^{\text{h}} \] ‘possibility’  \[\text{k}^{\text{h}}\text{астон} \] ‘I looked’  
\[\text{т}^{\text{h}}\text{ость} \] ‘eye’  \[\text{k}^{\text{h}}\text{арк}^{\text{h}} \] ‘hen’
Since aspirated and plain consonants appear at the end of the word ([tʰɔst] ‘eye,’ [tʰɔst] ‘honor’), the following context alone cannot govern aspiration. Focusing on what precedes the consonant, aspirates appear word-initially, or when preceded by a vowel or [r] (i.e. a sonorant) at the end of the word; unaspirated consonants appear when before or after an obstruent. It is possible to start with unaspirated consonants (as we did for English) and predict aspiration, but a simpler description emerges if we start from the assumption that voiceless stops are basically aspirated in Ossetic, and deaspirate a consonant next to an obstruent. The relative simplicity of the resulting analysis should guide your decisions about underlying forms, and not a priori decisions about the phonetic nature of the underlying segments that your analysis results in.

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

\[(38) \ ʃ \rightarrow s \text{ optional}\]

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

Optional rules may have environmental conditions on them. In Matuumbi, as we have seen in (24), voiced stops are implosive except after a nasal. The voiced velar stop exhibits a further complication, that after a vowel (but not initially) underlying /ŋ/ optionally becomes a fricative [ŋ] (the symbol “~” indicates “may also be pronounced as”).
Hence the optional realization of /ɠ/ as [ɣ], but only after a vowel, can be explained by the following rule.

\[(\text{ optionally realized as [ɣ] only after a vowel})\]

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

It would also be mistaken to think that there is one grammar for all speakers of English (or German, or Kimantuumbi) 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 speaker can actually pronounce words in multiple ways. In the case of Makonde, some speakers actually pronounce /ʃoomja/ in two different ways.

### Summary

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

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

1 Kuria
Provide rules to explain the distribution of the consonants $\beta, r, \gamma$ and $b, d, g$ in the following data. (Note that $r$ is a fricative consonant in this language.)

Accents mark tone: acute is high tone and “hacek” $\check{\text{c}}$ is rising tone.

<table>
<thead>
<tr>
<th>Kurian Word</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>aβaάnto</td>
<td>‘people’</td>
</tr>
<tr>
<td>amahilíndi</td>
<td>‘corn cobs’</td>
</tr>
<tr>
<td>eβá</td>
<td>‘forget!’</td>
</tr>
<tr>
<td>eyá</td>
<td>‘learn!’</td>
</tr>
<tr>
<td>hoorá</td>
<td>‘thresh!’</td>
</tr>
<tr>
<td>iβúrúŋúgúri</td>
<td>‘soft porridges’</td>
</tr>
<tr>
<td>báinu</td>
<td>‘you (pl)’</td>
</tr>
<tr>
<td>iβliingóna</td>
<td>‘grinding stones’</td>
</tr>
<tr>
<td>γαβα</td>
<td>‘carry a child!’</td>
</tr>
<tr>
<td>βρακά</td>
<td>‘ancestors’</td>
</tr>
<tr>
<td>γύúká</td>
<td>‘bring!’</td>
</tr>
<tr>
<td>καντά</td>
<td>‘smoothness’</td>
</tr>
<tr>
<td>oβότεéndééru</td>
<td>‘to count me’</td>
</tr>
<tr>
<td>okoómbára</td>
<td>‘to bewitch me’</td>
</tr>
<tr>
<td>okoóndsya</td>
<td>‘bite!’</td>
</tr>
<tr>
<td>romá</td>
<td>‘to ask me’</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Greek Word</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>kano</td>
<td>‘do’</td>
</tr>
<tr>
<td>xano</td>
<td>‘lose’</td>
</tr>
<tr>
<td>xino</td>
<td>‘pour’</td>
</tr>
<tr>
<td>krima</td>
<td>‘shame’</td>
</tr>
<tr>
<td>xufta</td>
<td>‘handful’</td>
</tr>
<tr>
<td>kali</td>
<td>‘charms’</td>
</tr>
<tr>
<td>xeli</td>
<td>‘eel’</td>
</tr>
<tr>
<td>xeri</td>
<td>‘hand’</td>
</tr>
<tr>
<td>kori</td>
<td>‘daughter’</td>
</tr>
<tr>
<td>xori</td>
<td>‘dances’</td>
</tr>
<tr>
<td>kìno</td>
<td>‘move’</td>
</tr>
<tr>
<td>krima</td>
<td>‘money’</td>
</tr>
<tr>
<td>xufeta</td>
<td>‘bonbons’</td>
</tr>
<tr>
<td>xali</td>
<td>‘plight’</td>
</tr>
<tr>
<td>xleri</td>
<td>‘candle’</td>
</tr>
<tr>
<td>oxì</td>
<td>‘no’</td>
</tr>
</tbody>
</table>

3 Farsi
Describe the distribution of the trills $r$, $r\j$ and the flap $\gamma$.

<table>
<thead>
<tr>
<th>Farsi Word</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>aëtej</td>
<td>‘army’</td>
</tr>
<tr>
<td>qædri</td>
<td>‘a little bit’</td>
</tr>
<tr>
<td>rast</td>
<td>‘right’</td>
</tr>
<tr>
<td>ahar</td>
<td>‘starch’</td>
</tr>
<tr>
<td>hæetowρ</td>
<td>‘however’</td>
</tr>
<tr>
<td>ahari</td>
<td>‘starched’</td>
</tr>
<tr>
<td>t’era</td>
<td>‘why?’</td>
</tr>
<tr>
<td>biræng</td>
<td>‘pale’</td>
</tr>
<tr>
<td>farsi</td>
<td>‘Persian’</td>
</tr>
<tr>
<td>rah</td>
<td>‘road’</td>
</tr>
<tr>
<td>ri</td>
<td>‘beard’</td>
</tr>
<tr>
<td>aaxær</td>
<td>‘last’</td>
</tr>
<tr>
<td>jir</td>
<td>‘lion’</td>
</tr>
<tr>
<td>bævadær</td>
<td>‘brother’</td>
</tr>
<tr>
<td>daird</td>
<td>‘you have’</td>
</tr>
<tr>
<td>fìini</td>
<td>‘pastry’</td>
</tr>
</tbody>
</table>
4 Osage
What rule governs the distribution of [d] versus [ð] in the following data?

<table>
<thead>
<tr>
<th>Osage</th>
<th>English</th>
</tr>
</thead>
<tbody>
<tr>
<td>dabr̥</td>
<td>‘three’</td>
</tr>
<tr>
<td>dat̊e</td>
<td>‘to eat’</td>
</tr>
<tr>
<td>dak̊e</td>
<td>‘to dig’</td>
</tr>
<tr>
<td>dali̊</td>
<td>‘good’</td>
</tr>
<tr>
<td>dali̱tu</td>
<td>‘to bite’</td>
</tr>
<tr>
<td>aok̊hãa</td>
<td>‘he lay down’</td>
</tr>
<tr>
<td>t’yeðe</td>
<td>‘he killed it’</td>
</tr>
<tr>
<td>ðɔeze</td>
<td>‘tongue’</td>
</tr>
<tr>
<td>ɔie</td>
<td>‘you’</td>
</tr>
<tr>
<td>ðɔiɔki</td>
<td>‘to wash’</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Amharic</th>
<th>English</th>
</tr>
</thead>
<tbody>
<tr>
<td>farɔs</td>
<td>‘horse’</td>
</tr>
<tr>
<td>jolahlidj</td>
<td>‘grandchild’</td>
</tr>
<tr>
<td>ganɔb</td>
<td>‘money’</td>
</tr>
<tr>
<td>ከ乜</td>
<td>‘I am’</td>
</tr>
<tr>
<td>mɔnɔnasat</td>
<td>‘get up’</td>
</tr>
<tr>
<td>ɔle</td>
<td>‘unarmed’</td>
</tr>
<tr>
<td>mat̊</td>
<td>‘when’</td>
</tr>
<tr>
<td>fəllaga</td>
<td>‘he wanted’</td>
</tr>
<tr>
<td>təmañat’</td>
<td>‘it got comfortable’</td>
</tr>
<tr>
<td>k’azɔɔ</td>
<td>‘he talked in his sleep’</td>
</tr>
<tr>
<td>lattif’</td>
<td>‘he shaved’</td>
</tr>
<tr>
<td>bakkɔla</td>
<td>‘it germinated’</td>
</tr>
<tr>
<td>tanɔsa</td>
<td>‘stand up!’</td>
</tr>
<tr>
<td>məjat</td>
<td>‘see’</td>
</tr>
<tr>
<td>d’sgna</td>
<td>‘brave’</td>
</tr>
<tr>
<td>mawdɔd</td>
<td>‘to like’</td>
</tr>
<tr>
<td>məmkɔ</td>
<td>‘advise’</td>
</tr>
<tr>
<td>jislañ</td>
<td>‘no’</td>
</tr>
<tr>
<td>məst’at</td>
<td>‘give’</td>
</tr>
<tr>
<td>agamnɔ</td>
<td>‘he found’</td>
</tr>
<tr>
<td>mɔkkɔ</td>
<td>‘he tried’</td>
</tr>
<tr>
<td>jɔti</td>
<td>‘he rubbed’</td>
</tr>
<tr>
<td>jɔmaggɔ</td>
<td>‘he became old’</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Gen</th>
<th>English</th>
</tr>
</thead>
<tbody>
<tr>
<td>agble</td>
<td>‘farm’</td>
</tr>
<tr>
<td>aŋli</td>
<td>‘ghost’</td>
</tr>
<tr>
<td>sabul</td>
<td>‘onion’</td>
</tr>
<tr>
<td>alɔ</td>
<td>‘hand’</td>
</tr>
<tr>
<td>avlo</td>
<td>‘bait’</td>
</tr>
<tr>
<td>drɛ</td>
<td>‘stretch arms’</td>
</tr>
<tr>
<td>exlɔ</td>
<td>‘friend’</td>
</tr>
<tr>
<td>hıl</td>
<td>‘read’</td>
</tr>
<tr>
<td>thɔɔ</td>
<td>‘exterminate’</td>
</tr>
<tr>
<td>klo</td>
<td>‘wash’</td>
</tr>
<tr>
<td>vlu</td>
<td>‘stretch a rope’</td>
</tr>
<tr>
<td>mla</td>
<td>‘pound a drum’</td>
</tr>
<tr>
<td>wla</td>
<td>‘hide’</td>
</tr>
<tr>
<td>eŋɔ</td>
<td>‘spouse’</td>
</tr>
<tr>
<td>eŋɛ</td>
<td>‘spitting cobra’</td>
</tr>
<tr>
<td>agonglo</td>
<td>‘lizard’</td>
</tr>
<tr>
<td>akplɔ</td>
<td>‘spear’</td>
</tr>
<tr>
<td>sra</td>
<td>‘strain’</td>
</tr>
<tr>
<td>atitrɔ</td>
<td>‘red-billed wood dove’</td>
</tr>
<tr>
<td>blafogbe</td>
<td>‘pineapple’</td>
</tr>
<tr>
<td>edɔ</td>
<td>‘dream’</td>
</tr>
<tr>
<td>exle</td>
<td>‘flea’</td>
</tr>
<tr>
<td>ɲəlo</td>
<td>‘write’</td>
</tr>
<tr>
<td>nrɔ</td>
<td>‘be ugly’</td>
</tr>
<tr>
<td>tre</td>
<td>‘glue’</td>
</tr>
<tr>
<td>lɔ</td>
<td>‘like’</td>
</tr>
<tr>
<td>pleplelu</td>
<td>‘laughing dove’</td>
</tr>
<tr>
<td>zro</td>
<td>‘fly’</td>
</tr>
<tr>
<td>etro</td>
<td>‘scale’</td>
</tr>
<tr>
<td>d’ro</td>
<td>‘hint’</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Shambaa</th>
<th>English</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘three’</td>
<td>‘he lay down’</td>
</tr>
<tr>
<td>‘to eat’</td>
<td>‘he killed it’</td>
</tr>
<tr>
<td>‘to dig’</td>
<td>‘tongue’</td>
</tr>
<tr>
<td>‘good’</td>
<td>‘you’</td>
</tr>
<tr>
<td>‘to bite’</td>
<td>‘to wash’</td>
</tr>
<tr>
<td>‘horse’</td>
<td>‘stand up!’</td>
</tr>
<tr>
<td>‘grandchild’</td>
<td>‘see’</td>
</tr>
<tr>
<td>‘money’</td>
<td>‘brave’</td>
</tr>
<tr>
<td>‘I am’</td>
<td>‘to like’</td>
</tr>
<tr>
<td>‘get up’</td>
<td>‘advise’</td>
</tr>
<tr>
<td>‘unarmed’</td>
<td>‘no’</td>
</tr>
<tr>
<td>‘when’</td>
<td>‘give’</td>
</tr>
<tr>
<td>‘he wanted’</td>
<td>‘he found’</td>
</tr>
<tr>
<td>‘it got comfortable’</td>
<td>‘he tried’</td>
</tr>
<tr>
<td>‘he shaved’</td>
<td>‘he rubbed’</td>
</tr>
<tr>
<td>‘he became old’</td>
<td>‘he started’</td>
</tr>
<tr>
<td>‘farm’</td>
<td>‘lizard’</td>
</tr>
<tr>
<td>‘ghost’</td>
<td>‘spear’</td>
</tr>
<tr>
<td>‘onion’</td>
<td>‘strain’</td>
</tr>
<tr>
<td>‘hand’</td>
<td>‘red-billed wood dove’</td>
</tr>
<tr>
<td>‘bait’</td>
<td>‘pineapple’</td>
</tr>
<tr>
<td>‘stretch arms’</td>
<td>‘dream’</td>
</tr>
<tr>
<td>‘friend’</td>
<td>‘flea’</td>
</tr>
<tr>
<td>‘read’</td>
<td>‘write’</td>
</tr>
<tr>
<td>‘exterminate’</td>
<td>‘be ugly’</td>
</tr>
<tr>
<td>‘wash’</td>
<td>‘glue’</td>
</tr>
<tr>
<td>‘stretch a rope’</td>
<td>‘like’</td>
</tr>
<tr>
<td>‘pound a drum’</td>
<td>‘laughing dove’</td>
</tr>
<tr>
<td>‘hide’</td>
<td>‘fly’</td>
</tr>
<tr>
<td>‘spouse’</td>
<td>‘scale’</td>
</tr>
<tr>
<td>‘spitting cobra’</td>
<td>‘hint’</td>
</tr>
</tbody>
</table>
8 Thai
The obstruents of Thai are illustrated below. Determine what the obstruent phonemes of Thai are ([p\textsuperscript{\textdegree}, t\textsuperscript{\textdegree}, k\textsuperscript{\textdegree}] are unreleased stops). Are [p\textsuperscript{\textdegree}, t\textsuperscript{\textdegree}, k\textsuperscript{\textdegree}] 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].

<table>
<thead>
<tr>
<th>Thai Word</th>
<th>Pronunciation</th>
</tr>
</thead>
<tbody>
<tr>
<td>tagi</td>
<td>'egg'</td>
</tr>
<tr>
<td>ni</td>
<td>'it is'</td>
</tr>
<tr>
<td>dodoa</td>
<td>'pick up'</td>
</tr>
<tr>
<td>ndimi</td>
<td>'tongues'</td>
</tr>
<tr>
<td>ɲtʰumbii</td>
<td>'monkey'</td>
</tr>
<tr>
<td>kitabu</td>
<td>'book'</td>
</tr>
<tr>
<td>ɲome</td>
<td>'cow'</td>
</tr>
<tr>
<td>goja</td>
<td>'sleep!'</td>
</tr>
<tr>
<td>ngoto</td>
<td>'heart'</td>
</tr>
<tr>
<td>ɲkʰuguni</td>
<td>'bedbug'</td>
</tr>
<tr>
<td>paalika</td>
<td>'fly!'</td>
</tr>
<tr>
<td>matagi</td>
<td>'eggs'</td>
</tr>
<tr>
<td>babu</td>
<td>'skin'</td>
</tr>
<tr>
<td>mbeu</td>
<td>'seed'</td>
</tr>
</tbody>
</table>

9 Palauan
Analyze the distribution of \(\delta\), \(\theta\) and \(\delta\) 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.

<table>
<thead>
<tr>
<th>Palauan Word</th>
<th>Pronunciation</th>
</tr>
</thead>
<tbody>
<tr>
<td>kədə</td>
<td>'we (inclusive)'</td>
</tr>
<tr>
<td>diak ~ diak</td>
<td>'negative verb'</td>
</tr>
<tr>
<td>tŋoθ</td>
<td>'tattoo needle'</td>
</tr>
<tr>
<td>diosəʔ ~ diosəʔ</td>
<td>'place to bathe'</td>
</tr>
<tr>
<td>kuθ</td>
<td>'louse'</td>
</tr>
<tr>
<td>koaθ</td>
<td>'visit'</td>
</tr>
<tr>
<td>ɲəɾaɾaɾə</td>
<td>'a village'</td>
</tr>
<tr>
<td>iədl</td>
<td>'short'</td>
</tr>
<tr>
<td>kədəb</td>
<td>'money'</td>
</tr>
<tr>
<td>udouθ</td>
<td>'my stone'</td>
</tr>
<tr>
<td>maθ</td>
<td>'eye'</td>
</tr>
<tr>
<td>əe:l ~ əe:l</td>
<td>'nail'</td>
</tr>
<tr>
<td>ɔik ~ dik</td>
<td>'wedge'</td>
</tr>
<tr>
<td>ədɔp</td>
<td>'visit'</td>
</tr>
<tr>
<td>əŋ</td>
<td>'sky'</td>
</tr>
<tr>
<td>əθ</td>
<td>'stone'</td>
</tr>
<tr>
<td>ənt</td>
<td>'ant'</td>
</tr>
<tr>
<td>ədi</td>
<td>'knew'</td>
</tr>
<tr>
<td>ɔləθak</td>
<td>'put together'</td>
</tr>
</tbody>
</table>
10 Quechua (Cuzco dialect)

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

qori 'gold'
qu'omir 'green'
mqo 'runt'
p'ul'u 'blanket'
suti 'name'
t'iliwi 'baby chick'
tl'añqañ 'granulate'
tqet' 'he disputes'
musoχ 'new'
jixqañ 'for free'
cq'el'a 'lazy'
t'eqañ 'straight'	noq 'r'
t'eqññ 'he hates'
axña 'thus'
qosa 'husband'
aliq 'dog'
karu 'far'
qaqñuna 'you (pl)'
t'eqññ 'pluck'
wateχ 'again'
waxtaj 'hitt' 
waqañ 'tears'
waxt'a 'poor'
t' Españ 'drop'

q'omir 'green'
hoq'ara 'deaf'
tjuñ 'he recalls'
omqoj 'be sick!'
tññññ 'he whispers'
tññññ 'toast'
tsíqo 'bird'
tññ 'ten'
t'ul' 'ice'
t'eqññ 'zigzagged'
t'ax 'field'
tññññ 'six'
lñl'a 'small shawl'
qaña 'skin'
señña 'nose'
atññ 'fox'
pusañ 'eight'
tññññ 'dry'
ahku 'let’s go'
kanq 'roasted'
tññññ 'poor'
tññññ 'known'

11 Lhasa Tibetan

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

angu ‘pigeon’
apsoo ‘shaggy dog’
amtö ‘a province’
uji ‘hair’
embo ‘deserted’
qawa ‘alphabet’

agññ ‘a number’
iyu ‘uncle’
uyi ‘forehead’
out ‘oh-oh’
qaña ‘foot’

æba ‘duck’
tukty ‘poison snake’
imñ ‘doctor’
eñ ‘bells’
qa ‘saddle’
qamba ‘pliers’
In this language, certain surface vowels can be predictably derived from other underlying vowels. Discover what vowels in this language are purely predictable, and give the rule which derives the predictable vowels.

12 Kirzan Armenian

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

Further reading
Cohn 1993; Halle 1959; Harris 1994; Kahn 1976; Sapir 1925.
This chapter explores the theory for 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 formalized in terms of these features
- see how these features make predictions about possible sounds and rules in human language

**KEY TERMS**

- observation
- predictions
- features
- natural classes
We have been casual about what sounds as cognitive units are made of, and just treated them as letters labeled by traditional articulatory descriptions. It is time now to raise a fundamental question: are segments further analyzed into “parts” that define them, or are they truly atomic – units which are not further divisible or analyzable?

### 3.1 Scientific questions about speech sounds

One of the scientific questions that need to be asked about language is: what is a possible speech sound? Humans can physically produce many more kinds of sounds than are used in language. 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 easily communicate an attitude). A goal of a scientific theory of language is to systematize such facts and explain them; thus we have discovered one limitation on language sound and its modality – language sounds are produced exclusively within the mouth and nasal passages, in the area between the lips and larynx.

Even staying within the vocal tract, languages also do not, for example, use whistles or inhalation to form speech sounds, nor is a labiolingual 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 Scandinavia, 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 has no systematic limitations short of anatomical ones, but in language, only a restricted range of sounds are used.

The issue of possible speech sounds is complicated by manual languages such as American Sign Language. ASL is technically not a counterexample to a claim about modality framed in terms of “speech sounds.” But it is arbitrary to declare manual language to be outside 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 is: what is the basis for defining possible speech sounds? Do we use our “speech anatomy” in every imaginable way, or only in certain well-defined ways?
3.1.1 Possible differences in sounds

One way to approach the question 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, you might expect that if a collection of languages had the same vowels transcribed as [i] and [ɪ], then these vowels should sound the same. This is not so.

Varieties of phonetic [i] vs. [ɪ]. Many languages have this pair of vowels; for example, Matuumbi has [i] and [ɪ]. But the actual pronunciation of [i] vs. [ɪ] differs between English and Matuumbi. Matuumbi [i] is higher than in English, and Matuumbi [ɪ] is a bit lower than English [i] – 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. (This is done in publications on Matuumbi, where the difference is notated as “extreme” ɨ, ʉ versus “regular” i, u.) Before we embark on a program of adding new symbols, we should be sure that we know how many symbols to add. It turns out that the pronunciation of [i] and [ɪ] differs in many languages: these vowels exist in English, Kamba, Lomwe, Matuumbi, Bari, Kipsigis, Didinga, and Sotho, and their actual pronunciation 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 [ɪ] is also very noticeable, and is something that a language learner must master to develop a good German or English accent. Although the differences may be difficult for the untrained ear to perceive at first, they are consistent, physically measurable, and reproducible by speakers. 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. Yet we do not introduce large numbers of new symbols to express these differences in pronunciations, because phonological symbols do not represent the precise phonetic properties of the sounds in a language, they only represent the essential contrast between sounds.

Other variants of sounds. Similar variation exists with other phonetic categories. The retroflex consonants of Telugu, Hindi, and Koti are all pronounced differently. Hindi has what might be called “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 (sublaminal); in Koti, the tongue is placed further forward, but is also sublaminal. 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 [ɣ] found in Arabic, Spanish, and the Kurdish language Hawrami are all phonetically different in subtle but audible ways.

The important details of speech. Although languages can differ substantially in the details of how their sounds are pronounced, there are limits on the types of sound differences which can be exploited contrastively, i.e. can form the basis for making differences in meaning. Language can contrast tense [i] and lax [ɪ], but cannot further contrast a hyper-tense high vowel (like that found in Matuumbi), which we might write as [i’], with plain tense [i] as in English, or hyper-lax [ɪ’] as in Matuumbi with plain lax [ɪ] as found in English. Within a language, you find at most [i] vs. [ɪ]. Languages can have one series of retroflex consonants, and cannot contrast Hindi-style [ʈ] with a Telugu-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 emphasize that such phonetic details are not too subtle to hear. The difference between various types of retroflex consonants is quite audible – otherwise, people could not learn the typical pronunciation of retroflex consonants in their language – and the difference between English and German [ɪ] is appreciable. Children learning German can hear and reproduce German [ɪ] accurately. Speakers can also tell when someone mispronounces a German [ɪ] as an English [i], and bilingual German–English speakers can easily switch between the two phonetic vowels.

One thing that 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 only 10 percent of these languages. Worse, this could only say what phonemic contrasts happen to exist at the present. A scientific account of language does not just ask what has been actually observed, it asks about the fundamental nature of language, including potential sounds which may have existed in a language spoken 1,000 years ago, or some future language which will be spoken 1,000 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 [ʘ] – 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 click consonants (Dahalo, Sotho, Zulu, Xhosa, Khoekhoe), so the question is whether the combination of concepts “bilabial” and “click” can define a phoneme. As it happens, we know that such a sound does exist, but only in two closely related languages, !Xoo and Eastern Hoan, members of the Khoisan language family. These languages have under 5,000 speakers combined, and given socioeconomic 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 on 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. We need a principled, theoretical basis for saying what we think might be observed.

**Predictions versus observations.** A list of facts is scientifically uninteresting. A basic goal of science is to have knowledge that goes beyond what has been observed, because we believe that the universe obeys general laws. A list might be 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 the attempt to discover laws that regulate the universe. Such laws make predictions about things that we have yet to observe: certain things should be found, other things should never be found.

The Law of Gravity predicts that a rock will fall to earth, which says what it will do and by implication what it will not do: it also won’t go up or sideways. Physicists have observed that subatomic particles decay into other particles. Particles have an 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 (K⁰); a kaon can decay into other particles known as “pions” (π) which also can be positive (π⁺), negative (π⁻) or neutral (π⁰). Thus a neutral kaon may become a positive pion and a negative pion (K⁰ → π⁺ + π⁻) or it may become one positive, one negative, and one neutral pion (K⁰ → π⁺ + π⁻ + π⁰), 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 (K⁰ → π⁺ + π⁺). In the myriad cases of particle decay which have been observed experimentally, none violates this law which predicts what can happen and what cannot.

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

### 3.1.2 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 kr kl gr gl
    *rp *lp *rb *lb *rt *rd *rk *lk *rg *lg

This restriction is very natural and exists in many languages—but it is not inevitable, and does not reflect any insurmountable problems of physiology or perception. Russian allows many of these clusters, for example [rtutj] ‘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 random fact from a list of accumulated facts if we have no basis for characterizing 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 i ɪ ĩ ė ĩ ə ɒ ʊ æ ɛ̃ ë̃ ě̃ ě̃ ɪ̃ ɪ̃ ʊ̃ ə ə̃ æ̃ ʊ̃

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 [tʃ], or the symbol [ø] with the symbol [œ], 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, tʃ, k\} \rightarrow \{m, n, ɲ, ŋ\} \_ \{m, n, ɲ, ŋ\}
    b.  \{b, p, d, q\} \rightarrow \{d, q, b, p\} \_ \{s, x, o, õ\}
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 definable 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 → tʃ, dʒ / _ 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 alveopalatal). The second rule cannot be characterized by phonetic properties: the sets {p, r}, {i, b}, and {o, n} are not defined by some phonetic property, and the change of [p] to [i] and [r] to [b] has no coherent phonetic characterization.

The lack of rules like (4b) is not just an isolated limitation of knowledge – it’s not simply that we haven’t found the specific rules (4b) but we have found (4a) – but rather these kinds of rules represent large, systematic classes. (3b) and (4b) represent a general kind of rule, 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. The second rule changes vowels into nasalized vowels before nasal consonants. The basis for defining these classes will be considered now.

### 3.2 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 F1 and F3 is reduced to half what it originally was, when the vowel appears before a consonant whose duration ranges from 100 to 135 ms.

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.

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.

The phonetic properties which are the basis of phonological systems are
general and somewhat abstract, such as voicing or rounding, and are
largely 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, 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 and 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 [+Fe]) or lacks the property (is [−Fe]). In this section, we follow Chomsky
and 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, and
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 characterized
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 [ε], 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
(important because it provides most 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, and this 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 is nearly equal, air stops flowing and voicing is blocked. So if the vocal tract is completely obstructed (as 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 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 ancillary actions to maintain voicing. 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.

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 and 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.

### 3.2.2 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 (syl):** forms a syllable peak (and thus can be stressed).
- **sonorant (son):** sounds produced with a vocal tract configuration in which spontaneous voicing is possible.
- **consonantal (cons):** 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], [j], [m],
[s], [t] are “consonants”) versus “vowel” (such as [a], [i]): indeed the only difference between the vowels [i, u] and the corresponding glides [j, w] is that [i, u] are [+syllabic] and [j, w] are [−syllabic]. The feature [syllabic] goes beyond the intuitive vowel/consonant split. English has syllabic sonorants, such as [ɹ], [l], [n]. The main distinction between the English words (American English pronunciation) ear [ɪɹ] and your [jɹ] resides in which segments are [+syllabic] versus [−syllabic]. In ear, the vowel [ɪ] is [+syllabic] and [ɹ] is [−syllabic], whereas in your, [j] is [−syllabic] and [ɹ] is [+syllabic]. The words eel [ɪl] and the reduced form of you’ll [j l] for many speakers of American English similarly differ in that [ɪ] is the peak of the syllable (is [+syllabic]) in eel, but [ɪ] 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 [r] with nonsyllabic [r] (cf. groze ‘fear (gen)’ versus groce ‘little throat’). Swahili distinguishes [mbuni] ‘ostrich’ and [mbuni] ‘coffee plant’ in the fact that [mbuni] is a three-syllable word and [m] is the peak (the only segment) of that first syllable, but [mbuni] is a two-syllable word, whose first syllable 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 a term quite frequently used by phonologists – almost always with the meaning “nonpeak” in the syllable, i.e. a [−syllabic] segment.

The definition of [sonorant] could be changed so that glottal configuration is also included, then 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.

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, with the result 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 constriction. In other languages there may be more constriction, but it 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, which is the essential property defining [+sonorant].

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 analyzed 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 r m] are members of the [+syllabic] class, and [j h ? r m s p] are members of the [−syllabic] class; [a r j ? r m] are in the [+sonorant] class and [s z p b] are in the [−sonorant] class; [a i w h ?] are in the [−consonantal] class and [r m 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].

When referring to segments defined by a combination of features, the features are written in a single set of brackets – [+cons, −syl] refers to a single segment which is both +consonantal and −syllabic, while [+cons] [−syl] refers to a sequence of segments, the first being +consonantal and the second being −syllabic.

Accordingly, the three major class features combine to define five maximally differentiated classes, exemplified by the following segment groups.

\[
\begin{array}{cccccccccc}
\text{syllabic} & + & + & - & - & - \\
\text{sonorant} & + & + & + & - & - \\
\text{consonantal} & - & + & - & + & + \\
\end{array}
\]
Further classes are definable by omitting specifications of one or more of these features: for example, the class \([-\text{syllabic}, +\text{sonorant}]\) includes \{j, w, h, ?, r, l, m\}.

One thing to note is that all \([+\text{syllabic}]\) segments, i.e. all syllable peaks, are also \([+\text{sonorant}]\). It is unclear whether there are syllabic obstruents, i.e. [s], [k]. 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 controversial. Another gap is the combination \([-\text{sonorant}, -\text{consonantal}]\), which would be a physical impossibility. A \([-\text{sonorant}]\) segment would require a major obstruction in the vocal tract, but the specification \([-\text{consonantal}]\) 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.

### 3.2.3 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 \([+\text{syllabic}, -\text{consonantal}, +\text{sonorant}]\) segments, and then proceed 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 involve considerable muscular effort.
- **advanced tongue root**: produced by drawing the root of the tongue forward.

The main features are \([\text{high}], [\text{low}], [\text{back}], \text{and} \ [\text{round}]\). Phonologists primarily distinguish just front and back vowels, governed by \([\text{back}]\): front vowels are \([-\text{back}]\) since they do not involve retraction of the tongue body, and back vowels are \([+\text{back}]\). Phonetic central vowels are usually treated as phonological back vowels, since typically central vowels are unrounded and back vowels are rounded. Distinctions such as those between \([i]\) and \([u], [s]\) and \([æ]\), \([y]\) and \([u], [s]\) and \([æ]\), or \([a]\) and \([a]\) are usually considered to be phonologically unimportant over-differentiations of language-specific phonetic values of phonologically back unrounded vowels. The phonologically relevant question about a vowel pronounced as \([u]\) is not whether the tongue position is intermediate between that of \([i]\) and \([u]\), but whether it patterns with \([i, e, y, o]\) or with \([u, u, o, æ]\) – or does it pattern apart from either set? 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 other feature for the front–back
dimension: though section 3.6 considers possible evidence for the phonological relevance of the concept “central vowel.” Given the phonologically questionable status of distinctive central vowels, no significance should be attributed to the use of the symbol [ɨ] versus [ɯ], and typographic convenience may determine that a [+back, –round] high vowel is typically transcribed as [i].

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) |
<table>
<thead>
<tr>
<th>i</th>
<th>y</th>
<th>i</th>
<th>u</th>
<th>e</th>
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<tbody>
<tr>
<td>high</td>
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<td>round</td>
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</table>

Note that [a] is a back low unrounded vowel, in contrast to the symbol [ɒ] for a back low rounded vowel.

Vowels with a laxer, “less deliberate,” and lower articulation, such as [i] in English sit or [ɛ] in English set, would be specified as [–tense].

(7) |
<table>
<thead>
<tr>
<th>i</th>
<th>y</th>
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<th>θ</th>
<th>θ</th>
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<tr>
<td>high</td>
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<tr>
<td>tense</td>
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</table>

Korean has a set of so-called “tense” consonants but these are phonetically “glottal” consonants.

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 in low vowels between tense and 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 i, or e and e 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 feature “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, 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 usually 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 a major constriction 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 airflow.

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 at or in front of the alveolar ridge (either at the lips, the teeth, or just back of the teeth) whereas other consonants (including laryngeals) are [−anterior], since they lack this front constriction. The best way to understand this feature is to remember that it is the defining difference between [s] and [ʃ], where [s] is [+anterior] and [ʃ] is [−anterior]. Anything produced where [s] is produced, or in front of that position, is [+anterior]; anything produced where [ʃ] is, or behind [ʃ], is [−anterior].

\[
\begin{array}{cccc}
\text{[+anterior]} & \text{[−anterior]} \\
\text{f} & \varphi & \text{p} & \theta & \text{s} & \text{t} \\
\end{array}
\]

\[
\begin{array}{cccc}
\text{[−anterior]} & \text{[+anterior]} \\
\text{ʃ} & \theta & \text{t} & \text{s} & \text{ʃ} & \text{n} & \text{l} & \text{r} & \text{n} & \text{t} \\
\end{array}
\]

Remember that the two IPA letters <tʃ> represent a single [−anterior] segment, not a combination of [+anterior] [t] and [−anterior] [ʃ].

Consonants which involve the blade or tip of the tongue are [+coronal], and this covers the dentals, alveolars, alveopalatal, 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.

\[
\begin{array}{cc}
\text{[+coronal]} & \text{[−coronal]} \\
\text{Ɂ} & \theta & \text{t} & \text{s} & \text{ʃ} & \text{n} & \text{l} & \text{r} & \text{n} & \text{t} \\
\text{p} & \varphi & \text{ʃ} & \text{k} & \text{q} & \text{ʕ} \\
\end{array}
\]
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 English alveolar [t], or alveopalatal [ʃ] from retroflex [ʂ]: the segments [t̪, ʃ] are [+distributed] and [t, ʂ] are [−distributed]. The feature [distributed], as applied to coronal consonants, approximately 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 noncoronal 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] vs. [f], [β] vs. [v], [θ] vs. [s], or [ø] vs. [z] the second sound in the pair is noisier. No specific degree of noisiness has been proposed which would allow you to determine in isolation whether a given sound meets the definition of strident or not. Thus it is impossible to determine whether [ʃ] is [+strident], since there is no contrast between strident and nonstrident alveopalatal sounds. The phoneme [ʃ] is certainly relatively noisy – noisier than [θ] – 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.

<table>
<thead>
<tr>
<th></th>
<th>p</th>
<th>t̪</th>
<th>t</th>
<th>tʃ</th>
<th>ṯ</th>
<th>c, k, q, ʕ, ?</th>
</tr>
</thead>
<tbody>
<tr>
<td>anterior</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>−</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td>coronal</td>
<td>−</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>−</td>
</tr>
<tr>
<td>distributed</td>
<td>+</td>
<td>−</td>
<td>+</td>
<td>−</td>
<td>−</td>
<td>−</td>
</tr>
</tbody>
</table>

**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 distin-
guished 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 traditional phonetic place of articulation for consonants is that of
“palatal” consonants. The term “palatal” is used in many ways, for example
the postalveolar or alveopalatal (palatoalveolar) consonants [ʃ] and [tʃ]
might be referred to as palatals. This is strictly speaking a misnomer, and the term
“palatal” is best used only for the “true palatal,” transcribed as [c ç ʃı]. Such
consonants are found in Hungarian, and also in German in words like [iç] ‘I’
or in Norwegian [çø:per] ‘buys.’ These consonants are produced with the body
of the tongue raised and fronted, and therefore they have the feature values
[+high, –back]. The classical feature system presented here provides no
way to distinguish such palatals from palatalized velars ([kɪ]) either phonet-
ically or phonologically. Palatalized (fronted) velars exist as allophonic vari-
ants of velars before front vowels in English, e.g. [kɪp] ‘keep’; they are
articulatorily and acoustically extremely similar to the palatals of Hungar-
ian. Very little phonological evidence is available regarding the treatment of
“palatals” versus “palatalized velars”: it is quite possible that [c] and [kɪ], or [ç]
and [xɪ], 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 articula-
tion for consonants can now be fully distinguished.

\[
\begin{array}{cccccccccccc}
& p & {\mathfrak{f}} & t & t{\mathfrak{f}} & t & c, k{\mathfrak{l}} & k & q & \mathfrak{s} & ? \\
\text{anterior} & + & + & + & - & - & - & - & - & - & - \\
\text{coronal} & - & + & + & + & - & - & - & - & - & - \\
\text{distributed} & + & - & + & - & + & + & - & - & - & - \\
\end{array}
\]

The typical vowel features have an additional function as applied to
consonants, namely that they define secondary articulations such as pal-
atalization and rounding. Palatalization involves superimposing the
raised and fronted tongue position of the glide [j] onto the canonical
articulation of a consonant, thus the features [+high, –back] are added
to the primary features that characterize a consonant (those being the
features that typify [i, j]). So, for example, the essential feature character-
istics of a bilabial are [+anterior, –coronal] and they are only incidentally
[–high, –back]. A palatalized bilabial would be [+anterior, –coronal,
+high, –back]. Velarized consonants have the features [+high, +back]

\[
\begin{array}{cccccccccccc}
& p & {\mathfrak{f}} & t & t{\mathfrak{f}} & t & c, k{\mathfrak{l}} & k & q & \mathfrak{s} & ? \\
\text{anterior} & + & + & + & - & - & - & - & - & - & - \\
\text{coronal} & - & + & + & + & - & - & - & - & - & - \\
\text{distributed} & + & - & + & - & + & + & - & - & - & - \\
\end{array}
\]
analogous to the features of velar consonants; pharyngealized consonants have the features [+back, -low]. Consonants may also bear the feature [round]. Applying various possible secondary articulations to labial consonants results in the following specifications.

\[(12)\]

<table>
<thead>
<tr>
<th></th>
<th>p</th>
<th>p'</th>
<th>p''</th>
<th>p''''</th>
<th>p''''</th>
<th>p''''''</th>
<th>p''''''''</th>
<th>p''''''''''</th>
</tr>
</thead>
<tbody>
<tr>
<td>high</td>
<td>–</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>back</td>
<td>–</td>
<td>–</td>
<td>+</td>
<td>–</td>
<td>+</td>
<td>+</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>low</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>+</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>round</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>+</td>
<td>+</td>
<td>–</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

Labialized (p'''), palatalized (p'), velarized (p'') and pharyngealized (p''') variants are the most common categories of secondary articulation. Uvularized consonants, i.e. p'''', are rare: uvularized clicks are attested in Ju/'hoansi. It is unknown if there is a contrast between rounded consonants differing in secondary height, symbolized above as p''' vs. p'' or p'''' vs. p''. 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 ([–high, +back]) and pharyngeals ([–high, +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 palatalized 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).

### 3.2.4 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 (cont):** the primary constriction is not narrowed so much that airflow through the oral cavity is blocked.

**delayed release (del.rel):** release of a total constriction is slowed so that a fricative is formed after the stop portion.

**nasal (nas):** the velum is lowered which allows air to escape through the nose.

**lateral (lat):** 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 notion “fricative” which refers to segments such as [s], [ʃ], or [θ].
The term “fricative” generally refers to nonsonorant continuants, i.e. the class defined by the conjunction of features [+continuant, −sonorant]. Since continuants are defined as sounds where air can flow continuously through the oral cavity, nasals like [m n ŋ] are [−continuant], even though they allow continuous airflow (through the nose).

Affricates such as [tʃ, pʃ] are characterized 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 [pʃ tʃ kʃ] do not act as a unified phonological class; nevertheless, some feature is needed to characterize stops versus affricates. Various alternatives have been proposed, for example that [kʃ] might just be the pronunciation of aspirated [kʰ] since velar [kʰ] and [kʃ] never seem to contrast; perhaps the feature [strident] defines [tʃ] vs. [t]. The proper representation of affricates is a currently unresolved issue in phonology.

The feature [+nasal] is assigned to sounds where air flows through the nasal passages, for example [n] as well as nasalized vowels like [ã]. Liquids and fricatives can be nasalized as well, but the latter especially are quite rare. L-like sounds are characterized 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) delayed release continuant lateral nasal

<table>
<thead>
<tr>
<th></th>
<th>t</th>
<th>n</th>
<th>tʰ</th>
<th>s</th>
<th>l</th>
<th>ɿ</th>
<th>t¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>spread glottis (s.g.)</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>+</td>
</tr>
<tr>
<td>constricted glottis (c.g.)</td>
<td>−</td>
<td>−</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>voice (voi)</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
</tbody>
</table>

### 3.2.5 Laryngeal features

Three features characterize the state of the glottis:

- **spread glottis** (s.g.): the vocal folds are spread far apart.
- **constricted glottis** (c.g.): the vocal folds are tightly constricted.
- **voice** (voi): the vocal folds vibrate.

Voiced sounds are [+voice]. The feature [spread glottis] describes aspirated obstruents ([pʰ], [bʰ]) and breathy sonorants ([m̩], [a̩]); [constricted glottis] describes implosives ([ɓ]), 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 realized 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 glottalized, 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, Khoekhoe (Nama) has a contrast between plain clicks ([!]’ān] ‘deep’) and glottalized ones ([!]’ám] ‘kill’), but the glottalized clicks realize 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 glottalized nonejective consonants in Korean or Khoekhoe is that they have the same phonological specifications, [−voice, +c.g.], but realize 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’  pʰ  bʰ
voice  −  +  +  −  −  +
c.g.   −  −  +  +  −  −
s.g.  −  −  −  −  +  +

3.2.6 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 and Halle (1968) account of features is a lack of features for tone. This is remedied in chapter 9 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 be concerned with languages having more than two tone levels until chapter 9.
3.2.7 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 [], 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, −distr]. If you do not know the phonetic characteristics of the segment symbolized as [], 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  tʃ  k  b  d  dʒ  g  f  v  θ  ð
syl    – – – – – – – – – – – –
son    – – – – – – – – – – – –
cons   + + + + + + + + + + + +
cont   – – – – – – – + + + + + +
del.rel – – + – – – + – – – – – –
lat    – – – – – – – – – – – –
nas    – – – – – – – – – – – –
voi    – – – – – – – – – – – –
c.g.   – – – – – – – – – – – –
s.g.   (− – – –) – – – – – – – –
ant   + + – – – + – – + + + +
cor    – + + – – + + – – – – – –
distr  – + – – + + +
high   – – – + – – – + – – – –
lo     – – – – – – – – – – – –
back   – – – + – – – + – – – –
round  – – – – – – – – – – – –

<table>
<thead>
<tr>
<th>s</th>
<th>z</th>
<th>ʃ</th>
<th>ʒ</th>
<th>h</th>
<th>ʔ</th>
<th>m</th>
<th>n</th>
<th>ŋ</th>
<th>l</th>
<th>j</th>
<th>w</th>
</tr>
</thead>
<tbody>
<tr>
<td>syl</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
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<td>–</td>
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<td>–</td>
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<tr>
<td>son</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
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<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>cons</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>–</td>
<td>–</td>
<td>+</td>
<td>+</td>
<td>–</td>
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<td>+</td>
<td>+</td>
</tr>
<tr>
<td>cont</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>del.rel</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>lat</td>
<td>–</td>
<td>–</td>
<td>–</td>
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<td>–</td>
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<td>–</td>
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<td>–</td>
<td>+</td>
</tr>
</tbody>
</table>
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, −ant, −lat, −distr]. Typically, vowels are also [+voice, −s.g., −c.g.]. There are languages such as Mazateco and !Xoo where breathy voicing and glottalization are contrastively used, 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). (Recall that we are not certain whether [tense] applies to low vowels.)

(16)

<table>
<thead>
<tr>
<th></th>
<th>i</th>
<th>y</th>
<th>i</th>
<th>u</th>
<th>e</th>
<th>ø</th>
<th>o</th>
<th>æ</th>
<th>ø</th>
<th>a</th>
<th>ø</th>
</tr>
</thead>
<tbody>
<tr>
<td>high</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td>low</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>back</td>
<td>−</td>
<td>−</td>
<td>+</td>
<td>+</td>
<td>−</td>
<td>−</td>
<td>+</td>
<td>−</td>
<td>−</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>round</td>
<td>−</td>
<td>+</td>
<td>−</td>
<td>−</td>
<td>+</td>
<td>+</td>
<td>−</td>
<td>+</td>
<td>−</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>tense</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

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 summarized 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 \([-\text{syl}, +\text{cont}, -\text{del.rel}, -\text{nas}, -\text{lat}, -\text{c.g.,} -\text{tense}, -\text{round}]\).

(17)

1: bilabial
2: labiodental
3: (inter-)dental
4: alveolar
5: alveopalatal
6: retroflex
7: palatal
8: velar
9: uvular
10: pharyngeal
11: glottal/laryngeal

\[\begin{array}{cccccccccccc}
\varphi & f & \theta & s & \acute{s} & \varsigma & x & \chi & h & h \\
\beta & v & \delta & z & \zeta & i & \gamma & \upsilon & \xi & \tilde{\eta} \\
1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 & 10 & 11
\end{array}\]

ant: ++++-+-+-
cor: ---+++---
distr: +++-
high: -+-+++---
lo: --+-++
back: +---++-

Secondary place of articulation is illustrated in (18), here restricted to secondary articulations on \([p\ t]\). All of these consonants are \([-\text{syl}, -\text{son, +cons, -cont, -del.rel, -lat, -nas, -voice, -s.g., -c.g., -tense}]\).

(18)

\[\begin{array}{cccccccccccc}
p & p^w & p^\gamma & p^j & p^\eta & t & t^w & t^\gamma & t^j & t^\varsigma & t^\tilde{\eta} \\
ant & ++++ & +++ & +++ & +++ & +++ & +++ & +++ & +++ & +++ & +++ \\
cor & --- & --- & --- & --- & --- & --- & --- & --- & --- & --- \\
distr & + & + & + & + & + & + & + & + & + & + \\
lo & + & + & + & + & + & + & + & + & + & + \\
back & + & + & + & + & + & + & + & + & + & + \\
round & + & + & + & + & + & + & + & + & + & + \\
\end{array}\]

Round consonants might simply have the specification \([+\text{round}]\). 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 velarized consonant.

A final important point must be made. The twenty-one 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. This 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 is better (see section 3.6 and chapter 9 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.

### 3.3 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).

\[
\begin{array}{cccc}
+\text{syl} & +\text{syl} & +\text{syl} & +\text{syl} \\
-\text{nas} & +\text{rd} & +\text{high} & +\text{nas} \\
-\text{high} & -\text{lo} & -\text{nas} & -\text{tense} \\
\end{array}
\]

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 i e e a a o o u u ρ]. 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 formalizing rules with features is recognizing the features which characterize classes. Discovering the features which define 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 y w j l m n a e i o u y

To assist in solving the problems which we will consider, feature matrices of these segments are given below in (21).
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 j l m n a e i o u y
     iv.  p k b g f x v γ
     v.   j l m n a e i
     vi.  v γ w j a e i o u y

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, there is no question of one solution being wrong in the technical sense (assuming the language has the segments of (20): if the language had [h], these two feature specifications would not describe the segments). 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

<table>
<thead>
<tr>
<th>(21)</th>
<th>cons</th>
<th>son</th>
<th>syl</th>
<th>voi</th>
<th>cont</th>
<th>nas</th>
<th>lat</th>
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[pʰ tʰ kʰ], then in specifying the set [p t k f s x], you would have to also mention [−s.g.] in order to achieve a definition of the set which excludes [pʰ tʰ kʰ].

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 j l m n ← Entire set of consonants

This set does not include glides; [consonantal] is the essential property which distinguishes glides (including h and ?, which are lacking here) from regular consonants. Thus, 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, you 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] segments of the language are in the set: the vowels {aeo} are 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 in 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, {j l m n a e i}, 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 {b d g v γ} 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) j l m n a e i  
    w j l m n a e i o u y

We can see that this set of segments is composed of a subset of sonorants, namely the sonorants excluding {w, o, u, y}. 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 \( \{v, \gamma\} \). 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.

\[
(25) \quad \{v, \gamma, w, j, a, e, i, o, u, y\} \\
    \{b, d, g, v, \gamma, w, j, l, m, n, a, e, i, o, u, y\}
\]

The fundamental difference between [b] and [v], or between [g] and [\(\gamma\)], is that \(\{b, g\}\) are stops while \(\{v, \gamma\}\) are continuants. This suggests using [+continuant] 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 \{l, m, n\}, which are [+voice]. We exclude the nasals via [+continuant] and add [+lateral] to exclude \(l\).

As a further exercise in understanding how sets of segments are grouped by the features, assume a language with the following segmental inventory.

\[
(26) \quad \{p, p, f, t, t, c, k, b, b, v, \beta, d, d, j, g, m, n, f, \theta, s, \i, d, \i, z, 3, i, y, e, 0, 3, o, u, a, w, j\}
\]

For each group, determine what feature(s) define the particular set of segments.

\[
(27) \quad \begin{align*}
    &i. \quad t, c, k, d, j, g, n, j, z, i, y, e, o, \circ, o, u, a, w, j \\
    &ii. \quad s, i, s, f, z, v, \beta, a, z, o, u, j, 0, y, a, w, 0 \\
    &iii. \quad k, j, g, c, w, i, u, y, j, n \\
    &iv. \quad k, g, a, n, n
\end{align*}
\]

### 3.4 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?

#### 3.4.1 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 the only possible phonemes. This gives a mathematical upper limit of \(2^n\) segments, given \(n\) binary features, so if there are twenty 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 nonexistence of a large class of such segments is independently explained. Similarly, no segment can be [+cons, −high, −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. [−ant] tells us that it must have a place of articulation behind the alveolar ridge, and [−high] 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. it must use just the features given by the theory, and physically possible.

Although the 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 sublaminal 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. Phonetic differences across languages are possible because phonetic interpretation is not subject to the limitations of phonological feature theory. Were we to discover such a contrast, the theory of features would be challenged, because it has no mechanism for expressing such a distinction. Similarly, the differences attested in the phonetics of [u] and [o] 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.

### 3.4.2 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 nasalization, which nasalizes all vowels before a nasal, can be formulated very simply if stated in features:

$$ (28) \quad [+\text{syllabic}] \rightarrow [+\text{nasal}] \quad \text{or} \quad [-\text{nasal}] $$
Such a rule is common in the languages of the world. Very uncommon, if it exists at all, is one nasalizing only the lax vowel $\text{ɪ}$, and only before $\text{m}$.

Formulated with features, that rule looks as follows:

$$(29) \begin{bmatrix} +\text{syl} \\ -\text{ATR} \\ +\text{high} \\ -\text{rd} \end{bmatrix} \rightarrow [+\text{nasal}] / _- \begin{bmatrix} +\text{nasal} \\ +\text{ant} \\ -\text{cor} \end{bmatrix}$$

This rule requires significantly more features than (28), since $\text{ɪ}$, which undergoes the rule, must be distinguished in features from other high vowels, such as $\text{i}$ or $\text{o}$, which (in this hypothetical case) do not undergo the rule, and $\text{m}$, which triggers the rule, must be distinguished from $\text{n}$ or $\text{ŋ}$, 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 important 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 nasal stops ($\text{n}, \text{m}, \text{ŋ}$), thus $\text{in} \rightarrow \text{ɨn}, \text{uw} \rightarrow \text{ʉnw}$, and so on. We would formulate such a rule as follows:

$$\text{(30)} \begin{bmatrix} +\text{syl} \\ +\text{high} \end{bmatrix} \rightarrow [+\text{nasal}] / _- \begin{bmatrix} +\text{nasal} \\ -\text{cont} \end{bmatrix}$$

However, we could equally well formalize the rule as:

$$\text{(31)} \begin{bmatrix} +\text{syl} \\ +\text{high} \\ -\text{low} \end{bmatrix} \rightarrow \begin{bmatrix} +\text{syl} \\ +\text{high} \\ -\text{low} \end{bmatrix} / _- \begin{bmatrix} +\text{nasal} \\ -\text{cont} \\ -\text{low} \end{bmatrix}$$

We could freely add $[-\text{low}]$ to the specification of the input segment (since no vowel can be $[+\text{high}, +\text{low}]$, thus high vowels automatically would pass that condition), and since the same class of vowels is referenced, inclusion of $[-\text{low}]$ is empirically harmless. Saying that the vowel becomes $[+\text{syl}, +\text{high}, -\text{low}]$ is harmless, since the vowel that undergoes the change already has these specifications. At the same time, the additional features in (31) are useless complications, so on the theoretical grounds of simplicity, we formalize the rule as (30). In writing phonological rules, we specify only features which are mandatory. A formulation like

$$\text{(32)} \begin{bmatrix} +\text{syl} \end{bmatrix} \rightarrow [+\text{nasal}] / _- \begin{bmatrix} +\text{nasal} \\ -\text{cont} \end{bmatrix}$$
would mention fewer features, but it would be wrong given the facts which the rule is supposed to account for, since the rule should state that only high vowels nasalize, but this rule nasalizes all vowels.

Likewise, we could complicate the rule by adding the restriction that only non-nasal vowels are subject to (30): in (30), we allow the rule to vacuously apply to high vowels that are already nasal. There is (and could be) no direct evidence which tells us whether /ĩn/ undergoes (30) and surfaces as [i̯n], or /ĩ̯n/ is immune to (30) and surfaces as [ın]; and there is no conceptual advantage to complicating the rule to prevent it from applying in a context where we do not have definitive proof that the rule applies. The standard approach to rule formalization is, therefore, to write the rule in the simplest possible way, consistent with the facts.

**Formalizability.** 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 \( \{p, r\} \rightarrow \{i, b\}/_{o, n} \). Since the segments being changed (\( p \) and \( r \)) or conditioning the change (\( o \) and \( n \)) cannot be defined in terms of any combination 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 characterizing the classes of segments that can function together for a rule. We now turn to a discussion of rule formalism, in the light of distinctive feature theory.

### 3.5 The formulation of phonological rules

Many aspects of rule theory were introduced in our informal approach to rule writing in chapter 2, and they carry over in obvious ways to the formal theory that uses features. The general form of a phonological rule is:

\[
\begin{array}{c}
\begin{bmatrix}
\alpha_{F_i} \\
\beta_{F_j} \\
\vdots
\end{bmatrix} \\
\begin{bmatrix}
\gamma_{F_k} \\
\delta_{F_l} \\
\vdots
\end{bmatrix} \\
\begin{bmatrix}
\epsilon_{F_m} \\
\zeta_{F_n} \\
\vdots
\end{bmatrix} \\
\begin{bmatrix}
\eta_{F_o} \\
\theta_{F_p} \\
\vdots
\end{bmatrix}
\end{array}
\rightarrow
\begin{bmatrix}
\alpha_{F_i} \\
\beta_{F_j} \\
\vdots
\end{bmatrix} \\
\begin{bmatrix}
\gamma_{F_k} \\
\delta_{F_l} \\
\vdots
\end{bmatrix} \\
\begin{bmatrix}
\epsilon_{F_m} \\
\zeta_{F_n} \\
\vdots
\end{bmatrix} \\
\begin{bmatrix}
\eta_{F_o} \\
\theta_{F_p} \\
\vdots
\end{bmatrix}
\]

**Focus**  **Structural change**  **Trigger**
where $F_i, F_j, F_k \ldots$ are features and $\alpha, \beta, \gamma \ldots$ are plus or minus values. The arrow means “becomes,” slash means “when it is in the context,” and the dash refers to the position of the focus in that context. 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 the target segment which are necessary for application of the rule. Instead of the slash, a rule can be formulated with the mirror-image symbol “%,” which means “before or after,” thus “$X \rightarrow Y% \_Z$” means “$X$ becomes $Y$ before or after $Z$."

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 $[\alpha F_i]$ as well as $[\beta F_j] \ldots$” 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:

$$\text{(34)} \quad [+\text{syl}] \rightarrow [+\text{long}] / _- [+]\text{son} \#$$

A rule which devoices a word-initial consonant would be written as:

$$\text{(35)} \quad [-\text{son}] \rightarrow [-\text{voice}] / # _-$$

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 /pata:mi/ ‘I fly’ does not undergo voicing. This rule is formulated as in (36).

$$\text{(36)} \quad [-\text{son}] \rightarrow [+\text{voice}] / _- # [+\text{son}]$$

Another symbol is the null, $\emptyset$, 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:

$$\text{(37)} \quad \begin{bmatrix} +\text{syl} \\ -\text{high} \\ -\text{long} \end{bmatrix} \rightarrow \emptyset / [+]\text{son} \_#$$
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 the monomorphemic word /tapta/ does not undergo deletion. Analogous to the word boundary, there is also a morpheme boundary symbolized by “+,” which can be used in writing rules. Thus the rule deleting the second of two consonants just in case the consonants are in different morphemes (hence a morpheme boundary comes between the consonants) is stated as:

\[ \text{(38) } [\text{--syl}] \rightarrow \emptyset / [\text{--syl}] +_ \]

You may encounter other conventions of formalism. One such notation is the brace notation. Whereas the standard matrix \([\ldots]\) refers to a conjunction of properties — segments which are A and B and C all at once — braces \(\{\ldots\}\) 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 a consonant or #. Such a rule can be written as (39).

\[ \text{(39) } [+syl] \rightarrow [\text{--long}] / [\text{--syl}] \{\text{--syl}\} \}

Most such rules use the notation to encode syllable-related properties, so in this case the generalization can be restated as “shorten a long vowel followed by a syllable-final consonant.” Using \([\ldots]\) as the symbol for a syllable boundary, this rule could then be reformulated as:

\[ \text{(40) } [+syl] \rightarrow [\text{--long}] / _ [\text{--syl}] \]

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 harmonize.
We can use the subscript-zero notation, and formalize the rule as in (42).

\[ [+\text{syl}] \rightarrow [+\text{rd}] / \left[ +\text{syl} \atop +\text{rd} \right] \]

The expression “\([-\text{syl}]_0\)” means “any number of \([-\text{syl}]\) 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 formalize one of the most common phonological rules in languages, the rule which assimilates a nasal in place of articulation to the following consonant, where \( /\text{mk}/ \rightarrow [\text{nk}], /\text{np}/ \rightarrow [\text{mp}] \) and so on. While we can write a rule which makes any nasal become \(+\text{ant}, +\text{cor}\) before a \(+\text{ant}, +\text{cor}\) consonant – any nasal becomes \([\text{n}]\) before \([\text{t}]\) – and we can write a rule to make any nasal \(+\text{ant}, -\text{cor}\) before a \(+\text{ant}, -\text{cor}\) consonant – nasals become \([\text{m}]\) before \([\text{p}]\) – we cannot express both changes in one rule.

\[ (+\text{nas}) \rightarrow \left[ +\text{ant} \atop +\text{cor} \right] / - \left[ +\text{ant} \atop +\text{cor} \right] \]

\[ (+\text{nas}) \rightarrow \left[ +\text{ant} \atop -\text{cor} \right] / - \left[ +\text{ant} \atop -\text{cor} \right] \]

Thus when the following consonant has the value \(+\text{cor}\) the nasal becomes \(+\text{cor}\) and when the following consonant has the value \(-\text{cor}\) the nasal becomes \(-\text{cor}\). We will return to issues surrounding this notation in chapter 9.

There are a couple of commonly used informal shorthand practices which you need to recognize. 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 than explicitly listing every feature with an associated variable, such a rule might be written as:

\[ (45) \quad \emptyset \rightarrow V_i / V_i C_C^# \]

meaning “insert a copy of the preceding vowel.”

### 3.6 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 3.1 is that the two kinds of phonetic retroflex consonants found in Hindi and Telugu cannot 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 and Halle, retroflex consonants were described with the feature [flat]. This feature was also used to describe rounding, pharyngealization, and uvulization. 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 pharyngealization. If a language has both [ʈ] and [kw], the surface differences in the realization of [flat], as retroflexion versus rounding, would be due to language-specific spell-out rules.

The theory would be falsified if you could show that rounding and pharyngealization are independent, and counterexamples were found. Arabic has the vowels [i a u] as well as pharyngealized vowels [iʕ aʕ uʕ], which derive by assimilation from a pharyngealized consonant. If rounding and pharyngealization are both described by the feature [flat], it is impossible to phonologically distinguish [u] and [uʕ]. But this is not at all inappropriate, since the goal is to represent phonological contrasts, not phonetic differences, because the difference between [u] and [uʕ] is a low-level phonetic one. The relevance of Arabic – whether it falsifies the feature [flat] – depends on what you consider to be the purpose of features.

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 (1961), and Ladefoged and 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.

Another prediction is that since uvular and round consonants are both [+flat], there should be no contrast between round and nonround uvulars, or between round velars and nonround uvulars, within a language. But a number of languages of the Pacific Northwest, including Lushootseed, have the contrast [k kʷ q qʷ]: this is a fact which is undeniably in the domain of phonology. 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. If [flat] indicates both retroflexion and rounding, it would be impossible to contrast [u] and [uˀ]. Such languages 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. Particular 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 of those features may lead to considerable changes in the predictions of the theory. Such changes should be undertaken with caution, taking note of unexpected consequences. If the theory changes frequently, 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 accommodate 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 coronal 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 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 and Halle (1968). However, problems were noticed in the theory without [labial].

The argument for adding [labial] is that it makes rules better formalizable. It was noticed that the following types of rules, inter alia, are frequently attested (see Campbell 1974, Anderson 1974).

(46) a. \( b \rightarrow w / C \)
   b. \( w \rightarrow b / [+\text{nasal}] \)
   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 \( b \rightarrow r \) is unattested.

(47) a. \[
\begin{array} {c}
+\text{ant} \\
-\text{cor} \\
+\text{voi}
\end{array}
\rightarrow
\begin{array} {c}
-\text{ant} \\
-\text{cons} \\
+\text{high} \\
+\text{bk} \\
+\text{rd}
\end{array}
/ C
\]
   b. \[
\begin{array} {c}
-\text{cons} \\
+\text{high}
\end{array}
\rightarrow
\begin{array} {c}
+\text{ant} \\
-\text{cor} \\
-\text{high} \\
-\text{rd}
\end{array}
\]

In the last rule of (46), no expression covers the class \( \{p, b, m, w, u, o\} \): rather they correspond to the disjunction \([+\text{ant}, -\text{cor}] \) or \([+\text{round}] \).

These rules can be expressed quite simply with the feature [labial].

(48) a. \[
\begin{array} {c}
+\text{labial} \\
+\text{voi}
\end{array}
\rightarrow
\begin{array} {c}
-\text{cons}
\end{array}
/ C
\]
   b. \[
\begin{array} {c}
+\text{labial}
\end{array}
\rightarrow
\begin{array} {c}
+\text{cons} \\
[+\text{nasal}]
\end{array}
\]
   c. \[
\begin{array} {c}
+\text{labial} \\
+\text{rd}
\end{array}
\rightarrow
\begin{array} {c}
+\text{cons} \\
-\text{rd}
\end{array}
\]
   d. \( i \rightarrow [+\text{labial}] / [+\text{labial}] \)
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 feature which might be redefined is [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, tʃ, k, m, n, ŋ, b, d, ɽ, 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, tʃ, k, m, n, ŋ, b, d, ɽ, 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, tʃ, k, b, d, ɽ, 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 2 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.

\[
\begin{align*}
(49) & \quad enɔq & \text{‘tree’} & \quad enɔq & \text{‘drum’} \\
& \quad ŋgɑq & \text{‘knife’} & \quad ekɑq & \text{‘leg’} \\
& \quad mσk & \text{‘dirt’} & \quad nδk & \text{‘European’} \\
& \quad pɔbrιk & \text{‘work project’} & \quad ajuk & \text{(person’s name)}
\end{align*}
\]
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 phonetically defined as being central.

Schwa does not cause lowering of k to q. In the standard account of vowels, [ɔ] differs from [ã] only in rounding, though phonetic tradition claims that these vowels also differ in being back ([ɔ]) versus central ([ã]). 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 formalizing the rule would be:

\[
(50) \begin{array}{c}
+\text{high} \\
+\text{back}
\end{array} \rightarrow \begin{array}{c}
-\text{high} \\
+\text{back} \\
+\text{high}
\end{array}
\]

If schwa is [+back, −high, −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 [ɔ] by requiring the trigger vowel to be [+round].

\[
(51) \begin{array}{c}
+\text{high} \\
+\text{back}
\end{array} \rightarrow \begin{array}{c}
-\text{high} \\
+\text{back} \\
-\text{high} \\
+\text{round}
\end{array}
\]

But this formulation is not correct either, since it would prevent the nonround low vowel [a] 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 characterizes 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 nonback round vowels. In many transcriptions of Norwegian, these are transcribed as [du] ‘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 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 [u] 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 \([\text{labial}]\), it is possible that the distinction lies in \([\text{labial}]\) versus \([\text{round}]\), where the out-rounded vowel \(<y>\) is \([+\text{round}, +\text{labial}]\) and in-rounded \(<u>\) is \([-\text{round}, +\text{labial}]\) – 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 \([\text{front}]\), which would allow the phonological definition of a class of central vowels, is that it defines unattested classes and segments outside the realm of vowels. The classical features could distinguish just \([k]\) and \([k']\), using \([-\text{back}]\). With the addition of \([\text{front}]\), we would have a three-way distinction between \(k\)-like consonants which are \([+\text{front}, -\text{back}], [-\text{front}, -\text{back}], \text{and } [-\text{front}, +\text{back}]\). But no evidence at all has emerged for such a contrast in any language. Finally, the addition of the feature \([\text{front}]\) defines a natural class \([-\text{back}]\) 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 \([\text{front}]\) 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 \([a]\) 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 nonlinear 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.
Exercises

1. Assume a segmental inventory composed of: [ʃ k t d s z n p b i u e o a w h]. Indicate what feature or features characterize the following classes of sounds.
   i. ʃ k u o a w
   ii. f p k h
   iii. f p b t s d z n
   iv. f u o w a b d z n i e

2. Given the segments [w j h ? i a o u u m l r m ρ t k q b d d γ], describe the following segment classes, being as economical as you can with your use of features.
   i. m l r m ρ t k q b d d γ
   ii. w j i a o u u m l r m ρ
   iii. w a o u n k q γ
   iv. w j h i a o u u l r d γ
   v. j i k d i
   vi. i a a o u u m

3. Assume the following segmental inventory:
   ρ t f q b d g s z γ n n l j i e o e æ

   Give the minimal feature description which identifies exactly the following subsets of the inventory:
   i. ρ t b s β n l
   ii. t f q b d s γ z n l e o e æ
   iii. p t f q b d ρ s β z n l e o e æ
   iv. q g γ n l o e
   v. f d g s j i e æ

4. State all of the features which are changed in each of the following rules:
   i. p → f
   ii. t → η
   iii. o → w
   iv. k → s
   v. s → t
   vi. a → i

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.
5. Formalize the following rules using distinctive features (segmental inventories to be assumed for each language are given after the rule in brackets). In each case, if the inventory includes segments [w x y z] and the rule is stated as changing [w] and [x], assume that /y, z/ can appear in the specified context and appear as [y, z] after the rule applies.

i. b, d, g → β, δ, γ / V _ 
   [p t k b d g β δ γ m n r i a a]
ii. Ω → j / i, e _ o, u, a 
   [p t k b d j w i y e æ o u a]
iii. t → s / _ 
   [p t k h v d s r l m n j i y e ð o u a]
iv. s → r / V_V 
   [p t k b d g s r l m n h w j e i o u a]
v. p, t → [t]/ _ i, e, a, o, u, k, t', η 
   [p t t' k n j e a o u]
vii. p, t, k → φ, θ, f, x / i e a o w j 
   [h _ _ i e a o r !]
vii. p, t', k, q → t / _ p, b, m, t, d, n 
   [p t t' k q b d g ð l r m n i u a r]
viii. k, g, η → k, g', η'/ p p' m b t t' n 
   [d t' d' n k g' η' f s x j _]
   [q f s s' j w i ð e o a æ]

6. Mixtec (San Miguel el Grande)

The causative form of the verb in Mixtec has a prefix, underlying /s/, which changes before certain consonants. Formalize a rule which accounts for these changes.

s-kaka 'make walk' s-haa 'make sprout'
ʃ-dibi 'make enter' s-taka 'gather'
s-taku 'make live' ʃ-lili 'tighten'
s-kunu 'make run' ʃ-ndata 'crack'
ʃ-d'ata 'overthrow'

7. Review previous solutions to exercises which you have done in the preceding chapter, and state the rules according to the features given here: discuss any problems which you may encounter in reformalizing these rules.

Further reading
Campbell 1974; Chomsky and Halle 1968; Jakobson and Halle 1956; Jakobson, Fant, and Halle 1952; Trubetzkoy 1939.
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 described 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 underlingly nasal or underlingly oral. If you assume that vowels are underlingly oral you can write a rule to derive all of the nasal vowels, and if you contrarily assume that vowels are all underlingly 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.

4.1 The importance of correct underlying forms

Neutralizing rules, on the other hand, are ones where two or more underlingly distinct segments have the same phonetic realization in some context because a rule changes one phoneme into another – thus the distinction of sounds is neutralized. This means that if you look at a word in this neutralized context, you cannot tell what the underlying segment is. Such processes force you to pay close 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
---|---
vagon | vagona
avtomobilj | avtomobilja
vet'er | vet'era
muʃ | mua
karandaʃ | karandaʃa
glas | glaza
golos | golosa
ras | raza
les | lesa
porok | poroga
vrak | vraga
urok | uroka
To give an explanation for the phonological processes at work in these data, you must give a preliminary description of the morphology. While morphological analysis is not part of phonology per se, it is inescapable that a phonologist must do a morphological analysis of a language, to discover the underlying form.

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 

<table>
<thead>
<tr>
<th>Nominative</th>
<th>Genitive</th>
</tr>
</thead>
<tbody>
<tr>
<td>t'vet</td>
<td>t'veta</td>
</tr>
<tr>
<td>prut</td>
<td>pruda</td>
</tr>
<tr>
<td>soldat</td>
<td>soldata</td>
</tr>
<tr>
<td>zavot</td>
<td>zavoda</td>
</tr>
<tr>
<td>xlep</td>
<td>xleba</td>
</tr>
<tr>
<td>grip</td>
<td>griba</td>
</tr>
<tr>
<td>trup</td>
<td>trupa</td>
</tr>
</tbody>
</table>

such as 

- vagon ~ vagona
- avtomobil ~ avtomobil'a
- vet ~ ve'tera

where, as it happens, the root ends with a sonorant consonant. The underlying forms of these noun stems are presumably /vagon/, /avtomobil'/, and /vet'/; no facts in the data suggest anything else. These underlying forms are thus 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 stems where the part of the word corresponding to the root is the same in all forms of the word: karandaʃ ~ karandaʃ'a, golos ~ golosa, les ~ lesa, urok ~ uroka, porok ~ poroka, t'vet ~ t'veta, soldat ~ soldata, and trup ~ trupa. However, in some stems, there are differences in the final consonant of the root, depending on whether we are considering the nominative or the genitive. Thus, we find the differences muʃ ~ muʒa, ~ glas ~ glaza, porok ~ poroga, vrak ~ vraga, prut ~ pruda, and xlep ~ xleba.

Such variation in the phonetic content of a morpheme (such as a root) is known as alternation. We can easily recognize 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 karandaʃ ~ karandaʃ'a, 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, chapter 2):

(2) $C \rightarrow [+\text{voice}] / V_2 V$

While applying this rule to the assumed underlying forms /glas-a/, /golos-a/, /ras-a/, and /les-a/ would give the correct forms glaza and raza, it would also give incorrect surface forms such as *goloza 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.

 You may be tempted to posit a rule that applies only in certain words, such as eye, time, and so on, but not voice, forest, etc. 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.

 The "nominative is underlying" hypothesis is fundamentally wrong: our failure to come up with an analysis is not because we cannot discern an obscure rule, but lies in the faulty assumption that we start with the nominative. That form has a consistent phonetic property, that any root-final obstruent (which is therefore word-final) is always voiceless, whereas in the genitive form there is no such consistency. If you look at the genitive column, the last consonant of the root portion of the word may be either voiced or voiceless.

 We now consider a second hypothesis, where we set up underlying representations for roots which distinguish stems which have a final voiced obstruent in the genitive versus those with a final voiceless obstruent. We may instead assume the following underlying roots.
Under this hypothesis, the genitive form can be derived easily. 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.

\[(4) \text{ Final devoicing} \]

\[ [\text{-son}] \rightarrow [\text{-voice}] / \_ \# \]

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.

Whether a consonant is voiced cannot be predicted in English ([dɛd] dead, [tɛd] Ted, [dɛt] debt), and must be part of the underlying form. Similarly, in Russian since you cannot predict whether a given root ends in a voiced or a voiceless consonant in the genitive, that information must be part of the underlying form of the root. That is information about the root, which cannot always be determined by looking at the surface form of the word itself: it must be discovered by looking at the genitive form of the noun, where the distinction between voiced and voiceless final consonants is not eliminated.

### 4.2 Refining the concept of 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.

This model implies that the output of one grammatical 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 to give the surface representation (which are then subject to principles of physical interpretation within the phonetic component). The output of the morphological component, which is the input to the phonology, is by definition 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 form 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 morpheme be pronounced as [s] as in cats or [ɪz] as in bushes.

It is very important to understand that the grammar does not formally derive one word from another. (Some languages seem to have special morphological processes, which we will not be discussing here, that derive one word from another – clipping such as Sally → Sal would be an example.) 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 concluded 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 symbolic representations whereas actually pronounced words are acoustic waveforms). It is a representation that is the foundation for explaining the variety of actual pronounciations found in the morpheme, as determined by phonological context.

The morphologically basic form of the Russian word for pond is the unmarked nominative, [prut], composed of just the root with no inflectional ending. In contrast, the phonological underlying form 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 4.6.

### 4.3 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 Ø (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)  

<table>
<thead>
<tr>
<th>Nominative sg</th>
<th>Partitive sg</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. ammu</td>
<td>ammua</td>
</tr>
<tr>
<td>hopea</td>
<td>hopeaa</td>
</tr>
<tr>
<td>katto</td>
<td>kattoa</td>
</tr>
<tr>
<td>kello</td>
<td>keloa</td>
</tr>
<tr>
<td>kirja</td>
<td>kirjaa</td>
</tr>
<tr>
<td>kylmae</td>
<td>kylææ</td>
</tr>
<tr>
<td>koulu</td>
<td>koulua</td>
</tr>
<tr>
<td>lintu</td>
<td>lintua</td>
</tr>
<tr>
<td>hylly</td>
<td>hyllyæ</td>
</tr>
<tr>
<td>kompelø</td>
<td>kompeløæ</td>
</tr>
<tr>
<td>nækø</td>
<td>nækøæ</td>
</tr>
<tr>
<td>b. joki</td>
<td>jokea</td>
</tr>
<tr>
<td>kivi</td>
<td>kiveæ</td>
</tr>
<tr>
<td>muuri</td>
<td>muuria</td>
</tr>
<tr>
<td>naapuri</td>
<td>naapuria</td>
</tr>
<tr>
<td>nimi</td>
<td>nimeæ</td>
</tr>
<tr>
<td>kaappi</td>
<td>kaappia</td>
</tr>
<tr>
<td>kaikki</td>
<td>kaikkea</td>
</tr>
<tr>
<td>kirehti</td>
<td>kirehtiaæ</td>
</tr>
<tr>
<td>lehti</td>
<td>lehtææ</td>
</tr>
<tr>
<td>mæki</td>
<td>mækeæ</td>
</tr>
<tr>
<td>ovi</td>
<td>ovea</td>
</tr>
<tr>
<td>posti</td>
<td>postia</td>
</tr>
<tr>
<td>tukki</td>
<td>tukkia</td>
</tr>
<tr>
<td>æiti</td>
<td>æitiæ</td>
</tr>
<tr>
<td>englanti</td>
<td>englantia</td>
</tr>
<tr>
<td>jærvi</td>
<td>jærveæ</td>
</tr>
<tr>
<td>koski</td>
<td>koskeaæ</td>
</tr>
<tr>
<td>reki</td>
<td>rekeæ</td>
</tr>
<tr>
<td>væki</td>
<td>vækeæ</td>
</tr>
</tbody>
</table>

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 -æ ~ -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. joki ~ jokea). 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 – compare jokea, nimeæ where [e] appears
before both [a] and [æ], versus *muuria, kibrehtia* 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 *tukka, kaikkea* versus *lehtie, aitie*.

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 *joki ~ jokea*, a second-language class on Finnish might simply have the student memorize a list of words like *joki ~ jokea* 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 one only considers the pronunciation of the nominative. This means: nominative forms are not the same as underlying forms (something that we also know given 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 can explain this alternation: of the eight vowels of Finnish [i, y, e, ø, æ, u, o, a], all of them appear at the end of the word except the vowel *e*. Now, since the stem of the word for ‘name,’ which appears as *nim*i 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 is in fact */nime/ . It would be a bit bizarre to assume an underlying form such as */nimai/, 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 actually composed of segments found in some surface manifestation of the morpheme. On the other hand, the stem of the word for ‘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 */muurii/ .

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

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*This is a natural assumption but not an absolute rule, as we see in chapter 8. 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.*
underlying representations such as /joke/, /nimel/, /kivel/, /lehtel/, /love/, and so on, as well as /muuri/, /naapuri/, /kaappi/, /tukki/, and so on. The underlying form of partitive [joke-a] would thus be /joke-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 [jok], which derives from /joke/. 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

\[
\begin{array}{c}
\text{[+syl]} \\
\text{[−rd]} \\
\text{[−back]} \\
\text{[−lo]} \\
\end{array}
\rightarrow [\text{[+high]}] / \_\_\_
\]

This rule is neutralizing since the distinction between /i/ and /e/ is neutralized 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.

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

(8) Infinitive 1sg habitual 3sg habitual Imperative

<table>
<thead>
<tr>
<th>Kerewe</th>
<th>mpaamba</th>
<th>apaamba</th>
<th>paamba</th>
<th>‘adorn’</th>
</tr>
</thead>
<tbody>
<tr>
<td>kupamba</td>
<td>mpaamba</td>
<td>apaamba</td>
<td>paamba</td>
<td>‘line up’</td>
</tr>
<tr>
<td>kupanga</td>
<td>mpaanga</td>
<td>apaanga</td>
<td>paanga</td>
<td>‘measure’</td>
</tr>
<tr>
<td>kupuupa</td>
<td>mpuupa</td>
<td>apuupa</td>
<td>puupa</td>
<td>‘be light’</td>
</tr>
<tr>
<td>kupeketʃa</td>
<td>mpeketʃa</td>
<td>apektʃa</td>
<td>peketʃa</td>
<td>‘make fire’</td>
</tr>
<tr>
<td>kupinda</td>
<td>mpiinda</td>
<td>apiinda</td>
<td>piinda</td>
<td>‘be bent’</td>
</tr>
<tr>
<td>kuhiiga</td>
<td>mpiiga</td>
<td>ahiiga</td>
<td>hiiga</td>
<td>‘hunt’</td>
</tr>
<tr>
<td>kuheeka</td>
<td>mpeeka</td>
<td>aheeka</td>
<td>heeka</td>
<td>‘carry’</td>
</tr>
<tr>
<td>kuhaanga</td>
<td>mpaanga</td>
<td>ahaanga</td>
<td>haanga</td>
<td>‘create’</td>
</tr>
<tr>
<td>kuheeba</td>
<td>mpeeba</td>
<td>aheeba</td>
<td>heeba</td>
<td>‘guide’</td>
</tr>
<tr>
<td>kuhiima</td>
<td>mpiima</td>
<td>ahiima</td>
<td>hiima</td>
<td>‘gasp’</td>
</tr>
<tr>
<td>kuhuuhua</td>
<td>mpuuha</td>
<td>ahuuha</td>
<td>huuha</td>
<td>‘breathe into’</td>
</tr>
</tbody>
</table>
We notice that every infinitive begins with *ku-* which we surmise is the prefix for the infinitive; the third-singular habitual form has the prefix *a-* and the first-singular 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 first-singular 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 underlyingly /peeba/, or the stem is underlyingly /heeba/. If we assume that the stem is underlyingly /heeba/, we require a rule to explain the divergence between the predicted form of the first-singular 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.

(9) Postnasal hardening

\[ [+s.g.] \rightarrow [-cont] / [+nas] \]

If, on the other hand, we assume that the root 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) \[ [+ant] \rightarrow [+s.g. / [+cor] \rightarrow [-ant] / [+voi] \rightarrow [-cont] \]

This suggests that rule (10) is wrong.

More important than the greater complexity of the rule entailed by assuming that the word for ‘guide’ is underlyingly /peeba/, it is empirically wrong: rule (10) implicitly claims that /p/ should always become [h] word-initially or after a vowel, but this is falsified by forms such as *kupaamba, apaamba, paamba ‘adorn’ and kupaanga, apaanga, paanga ‘line up.’ If we assume that the stems uniformly begin with /p/, then we cannot predict whether the imperative or infinitive has [h] (kuhaanga) or [p] (kupaanga). On the other hand, if we assume an underlying contrast between initial /h/ and initial /p/ – i.e. *haanga ‘create,’ paanga ‘arrange’ – then we 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 (mpaaanga ‘I create; ‘I arrange’).
The rule formalization in (9) exploits a widely used notion about how rules apply, known as **structure preservation**. Notice that the structural change specified mentions only that /h/ becomes \([-\text{cont}, +\text{ant}\])\], which are two features that characterize the difference between /h/ and [p]. There are two other actual changes in feature which are not explicitly mentioned, namely that the segment becomes \([+\text{cons}, –\text{son}]\). These values can be automatically predicted from the fact that in this language, there is only one voiceless \([+\text{ant}, –\text{cor}]\) stop, namely [p]. The idea underlying structure preservation is that each language defines an inventory of segments, and the structural change of a rule changes from one sound within the inventory to another sound. Specifying that change as \([-\text{cont}, +\text{ant}, +\text{cons}, –\text{son}]\) fully specifies what the result of the rule is, but \([-\text{cont}, +\text{ant}]\) identifies the same unique segment of the language, more economically.

**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 [iz], to be discussed later).

<table>
<thead>
<tr>
<th>(11)</th>
<th>kaeps</th>
<th>caps</th>
<th>kæbz</th>
<th>cabs</th>
<th>klæmz</th>
<th>clams</th>
</tr>
</thead>
<tbody>
<tr>
<td>kæts</td>
<td>cats</td>
<td>kædz</td>
<td>cads</td>
<td>kænz</td>
<td>cans</td>
<td></td>
</tr>
<tr>
<td>kaks</td>
<td>cocks</td>
<td>kagz</td>
<td>cogs</td>
<td>kaz</td>
<td>cars</td>
<td></td>
</tr>
<tr>
<td>puwfs</td>
<td>proofs</td>
<td>hovz</td>
<td>hooves</td>
<td>gålz</td>
<td>gulls</td>
<td></td>
</tr>
<tr>
<td>flîz</td>
<td>plæwz</td>
<td>plows</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pjiez</td>
<td>purees</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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 third-singular present-tense form of verbs.

<table>
<thead>
<tr>
<th>(12)</th>
<th>slæps</th>
<th>slaps</th>
<th>stæbz</th>
<th>stabs</th>
<th>slæmz</th>
<th>slams</th>
</tr>
</thead>
<tbody>
<tr>
<td>hıts</td>
<td>hits</td>
<td>hajdz</td>
<td>hides</td>
<td>kænz</td>
<td>cans</td>
<td></td>
</tr>
<tr>
<td>powks</td>
<td>pokes</td>
<td>dğz</td>
<td>digs</td>
<td>hænj</td>
<td>hangs</td>
<td></td>
</tr>
<tr>
<td>laęfs</td>
<td>lauıhs</td>
<td>θırajvz</td>
<td>thriving</td>
<td>hijlz</td>
<td>heals</td>
<td></td>
</tr>
<tr>
<td>pıths</td>
<td>pıths</td>
<td>bejöz</td>
<td>bathes</td>
<td>huz</td>
<td>hears</td>
<td></td>
</tr>
<tr>
<td>flajz</td>
<td>flajz</td>
<td>flies</td>
<td>vıjtowz</td>
<td>vıtoes</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

If we suppose that the underlying form of the affixes for noun plural and third-singular present verbs is [iz], then we would assume the following rule to derive the phonetic variant [s].

| (13)    | –son | \([-\text{voice}] / [+\text{voice}]\) |
On the other hand, if we were to assume that these suffixes are under-
lyingly /s/, we would assume the following rule.

\[(14)\] \[-son\] \[+voice\] / [+voice] \_

In terms of the simplicity and generality of these two rules, the analyses
are comparable. Both formulations require the same number of phon-
etic 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 *[jəkdl], *[pifz], *[sdap]. The implicit pre-
diction 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, [fæls] false. We prefer a hypothesis which
makes the correct prediction about the phonetic structure of the lan-
guage as a whole, and thus we select the underlying form /z/ and a rule
devoicing obstruents after voiceless segments. Looking for such asym-
metries plays an important role in determining which of two hypotheses
is the correct one.

The alternation \(z \sim s\) is not limited to the two affixes -z ‘plural’ and -z
‘3sg present tense.’ The rule of devoicing can also be seen applying to the
possessive suffix -z.

\[(15)\] \begin{align*}
Noun & \quad Noun + \text{poss.} \\
\text{kæt} & \quad \text{kæts} \quad \text{cat} \\
\text{slæg} & \quad \text{slægz} \quad \text{slug} \\
\text{klæm} & \quad \text{klæmz} \quad \text{clam} \\
\text{snow} & \quad \text{snowz} \quad \text{snow}
\end{align*}

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.

\[(16)\] \begin{align*}
\text{Noun + has} & \quad \text{Reduced} & \quad \text{Noun + is} & \quad \text{Reduced} \\
d\text{æk} \text{hæz i?n} & \quad d\text{æks i?n} & \quad d\text{æk i?n} & \quad d\text{æks i?n} \quad \text{Jack} \\
p\text{æt hæz i?n} & \quad p\text{æts i?n} & \quad p\text{æt i?n} & \quad p\text{æts i?n} \quad \text{Pat} \\
d\text{æn hæz i?n} & \quad d\text{ænz i?n} & \quad d\text{æn i?n} & \quad d\text{ænz i?n} \quad \text{Jen} \\
\text{bæz hæz i?n} & \quad \text{babz i?n} & \quad \text{bab i?n} & \quad \text{babz i?n} \quad \text{Bob} \\
d\text{ow hæz i?n} & \quad d\text{owz i?n} & \quad d\text{ow i?n} & \quad d\text{owz i?n} \quad \text{Joe}
\end{align*}

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 (Tanzania), concentrating on the tones of morphemes (H or high tone is marked with acute accent, L or low-toned syllables are unmarked).

(17) a. okušuma ‘to hit’   okusiša ‘to block’
    okušumira ‘to hit for’   okusiriša ‘to block for’
    okušumana ‘to hit e.o.’   okusirišana ‘to block e.o.’
    okušumirana ‘to hit for e.o.’   okusiriširana ‘to block for e.o.’

b. okulúma ‘to bite’   okukúša ‘to fold’
    okulumíra ‘to bite for’   okukúšíra ‘to fold for’
    okulumána ‘to bite e.o.’   okukúšína ‘to fold e.o’
    okulumírana ‘to bite for e.o.’   okukúšírana ‘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: -šum- ‘hit,’ -šif- ‘block,’ as well as -šum- ‘bite’ and -šúf- ‘fold.’ We decide that ‘bite’ and ‘fold’ underlyingly have H tones in part based on the fact that there actually is an 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 an 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) okumušúma ‘to hit him/her’   okumusiša ‘to block him/her’
    okumušumíra ‘to hit for him/her’   okumusišíra ‘to block for him/her’
    okutšúma ‘to hit it’   okutšiša ‘to block it’
    okutšúmíra ‘to hit for it’   okutšišíra ‘to block for it’

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

4.4 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 (Mariana Islands).

(19)  

<table>
<thead>
<tr>
<th>Chamorro</th>
<th>Translation</th>
</tr>
</thead>
<tbody>
<tr>
<td>gwíhán</td>
<td>‘fish’</td>
</tr>
<tr>
<td>gúma?</td>
<td>‘house’</td>
</tr>
<tr>
<td>káttta</td>
<td>‘letter’</td>
</tr>
<tr>
<td>t’úpa</td>
<td>‘cigarettes’</td>
</tr>
<tr>
<td>fíno?</td>
<td>‘talk’</td>
</tr>
<tr>
<td>túnú?</td>
<td>‘to know’</td>
</tr>
<tr>
<td>t’úgo?</td>
<td>‘juice’</td>
</tr>
<tr>
<td>sóŋsuŋ</td>
<td>‘village’</td>
</tr>
<tr>
<td>húlu?</td>
<td>‘up’</td>
</tr>
<tr>
<td>pét’u</td>
<td>‘chest’</td>
</tr>
<tr>
<td>tóm’tu</td>
<td>‘knee’</td>
</tr>
<tr>
<td>ótdut</td>
<td>‘ant’</td>
</tr>
<tr>
<td>óksu?</td>
<td>‘hill’</td>
</tr>
<tr>
<td>dánjkulu</td>
<td>‘big one’</td>
</tr>
<tr>
<td>láhi</td>
<td>‘male’</td>
</tr>
<tr>
<td>lágu</td>
<td>‘north’</td>
</tr>
<tr>
<td>pulónnun</td>
<td>‘trigger fish’</td>
</tr>
<tr>
<td>mundóngu</td>
<td>‘cow’s stomach’</td>
</tr>
<tr>
<td>putamonédá</td>
<td>‘wallet’</td>
</tr>
<tr>
<td>i gwíhán</td>
<td>‘the fish’</td>
</tr>
<tr>
<td>i gúma?</td>
<td>‘the house’</td>
</tr>
<tr>
<td>jø? káttta</td>
<td>‘a letter (object)’</td>
</tr>
<tr>
<td>i káttta</td>
<td>‘the letter’</td>
</tr>
<tr>
<td>i t’úpa</td>
<td>‘the cigarettes’</td>
</tr>
<tr>
<td>mi fíno?</td>
<td>‘lots of talk’</td>
</tr>
<tr>
<td>en túnú?</td>
<td>‘you know’</td>
</tr>
<tr>
<td>mi t’úgo?</td>
<td>‘lots of juice’</td>
</tr>
<tr>
<td>i sóŋsuŋ</td>
<td>‘the village’</td>
</tr>
<tr>
<td>xe’n húlu?</td>
<td>‘upward’</td>
</tr>
<tr>
<td>i pét’u</td>
<td>‘the chest’</td>
</tr>
<tr>
<td>i tému</td>
<td>‘the knee’</td>
</tr>
<tr>
<td>mi ótdut</td>
<td>‘lots of ants’</td>
</tr>
<tr>
<td>gi óksu?</td>
<td>‘at the hill’</td>
</tr>
<tr>
<td>i dánjkulu</td>
<td>‘the big one’</td>
</tr>
<tr>
<td>i láhi</td>
<td>‘the male’</td>
</tr>
<tr>
<td>xe’n lágu</td>
<td>‘toward north’</td>
</tr>
<tr>
<td>i pulónnun</td>
<td>‘the trigger fish’</td>
</tr>
<tr>
<td>i mundóngu</td>
<td>‘the cow’s stomach’</td>
</tr>
<tr>
<td>i putamonédá</td>
<td>‘the wallet’</td>
</tr>
</tbody>
</table>

What underlying representations, and what rule or rules, are required to account for these data? When you answer this question, you should consider two hypotheses which differ in terms of 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 in (20), the imperative, seems to involve a vowel suffix. One reason to think that there is an imperative suffix is that every imperative ends either in the vowel a or in ø (the choice between a versus ø is based on the vowel which precedes that suffix, /a/ or /ø/ versus other vowels, and can be ignored here). A second reason comes from comparing the
imperative and the plain present forms. Comparing ana and anninta, or kama and kamninta, we can see that for each verb, the portions common to both the imperative 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 imperative, and another suffix -ninta which marks the plain present.

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 first-singular possessive prefix in Koasati (Louisiana), and what phonological rule applies in these examples?
Matuumbi. What phonological rules pertaining to consonants operate in the following examples from Matuumbi? What are the underlying forms of the stems of the words for ‘rope,’ ‘palm,’ ‘tongue,’ ‘piece of wood,’ ‘pole,’ and ‘covered’? Ignore tonal changes.

(22) 

<table>
<thead>
<tr>
<th>Singular</th>
<th>Plural</th>
</tr>
</thead>
<tbody>
<tr>
<td>lugóí</td>
<td>ngóí</td>
</tr>
<tr>
<td>lugolóká</td>
<td>ngolóká</td>
</tr>
<tr>
<td>lubáu</td>
<td>mbáu</td>
</tr>
<tr>
<td>lubágalo</td>
<td>mbagálo</td>
</tr>
<tr>
<td>ludʒiíŋjá</td>
<td>ndʒiíŋjá</td>
</tr>
<tr>
<td>lulaála</td>
<td>ndaála</td>
</tr>
<tr>
<td>lulimí</td>
<td>ndími</td>
</tr>
<tr>
<td>lulindiílá</td>
<td>ndndíílá</td>
</tr>
<tr>
<td>lupaláaí</td>
<td>mbaláaí</td>
</tr>
<tr>
<td>lupaaáí</td>
<td>mbaaáí</td>
</tr>
<tr>
<td>lutéélá</td>
<td>ndéélá</td>
</tr>
<tr>
<td>luklígo</td>
<td>nglígo</td>
</tr>
<tr>
<td>luklí</td>
<td>nglíi</td>
</tr>
<tr>
<td>lujímá</td>
<td>ndjíma</td>
</tr>
<tr>
<td>lujóka</td>
<td>ndjóka</td>
</tr>
<tr>
<td>lujúsí</td>
<td>ndjúsí</td>
</tr>
<tr>
<td>lujúwé</td>
<td>ndjúwe</td>
</tr>
<tr>
<td>luwikílíjá</td>
<td>ng“wíkílíjá</td>
</tr>
</tbody>
</table>

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. You should be able to explain these alternations with two rules. In formalizing the rules, pay attention to the concept of structure preservation in rules.

4.5 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 neutralized in a related word where the conditions for the rule are present. We now consider two additional cases where underlying distinctions are neutralized 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.
4.5.1 Korean final Cs

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 for ‘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 for ‘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 the word for ‘rice’ is pronounced as [m].

(23) a. pap  
apmækat’a  
rice  
didn’t-eat  
apm winmoke  
tuət’a  
rice  
on-upper-floor  
put  
apm samakat’a  
rice  
ate-at-store  
apm totuki  
humtʰəkat’a  
rice  
thief-(subj)  
stole

b. pam  
man  
məkələ  
rice  
lot  
man  
əmak-imjən  
rice  
eat-if  
man  
ənamu  
masik’ə  
əmak’tə  
rice  
very  
deliciously  
man  
hək’o  
rice  
add

Compare those examples with the following examples with the word for ‘chestnut.’

(24) a. pam  
apmækat’a  
chestnut  
didn’t-eat  
apm winmoke  
tuət’a  
chestnut  
on-upper-floor  
put  
apm samakat’a  
chestnut  
ate-at-store  
apm totuki  
humtʰəkat’a  
chestnut  
thief-(subj)  
stole

b. pam  
man  
məkələ  
chestnut  
lot  
man  
əmak-imjən  
chestnut  
eat-if

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

The last consonant of the word for ‘chestnut’ is always [m], so we would
presume that the underlying form of that word is /pam/. Since the word for
‘rice’ varies between [pap] and [pam], and since we know that the under-
lying 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 underlying form of the word for
‘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.

4.5.2 Matuumbi tone

In the Korean case which we just considered, it happens that the under-
lying form of the word is the same as the way the word is pronounced
when it is said alone. This situation does not hold in Matuumbi, 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 an 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)  kiwikiljo ‘cover’  nga kikiljo lí ‘it isn’t a cover’
lubágalo ‘lath’  nga lubagalo lí ‘it isn’t a lath’
mikóta ‘sugar canes’  nga mikota lí ‘it isn’t sugar canes’
nguúnguni ‘bedbug’  nga ngunguni lí ‘it isn’t a bedbug’
lukólogo ‘brewery’  nga lukologo lí ‘it isn’t a brewery’
mabándo ‘thighs’  nga mabaando lí ‘it isn’t thighs’
kikóloombe ‘shell’  nga kikoloome lí ‘it isn’t a shell’
liptanaongo ‘rainbow’  nga liptanaongo lí ‘it isn’t a rainbow’

In contrast, the words of (26), which also have an 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)  lukóngobe ‘wood’  nga lukóngobe lí ‘it’s not wood’
kitókotoko ‘quelea bird’  nga kitókotoko lí ‘it’s not a quelea’
diíwai ‘wine’  nga diíwai lí ‘it’s not wine’
lukóongono ‘chicken leg’  nga lukóongono lí ‘it’s not a leg’
lukóongowe ‘marble’  nga lukóongowe lí ‘it’s not marble’
matógolo  ‘waterbucks’  nga matógolo lí  ‘it’s not waterbucks’

miviřingo  ‘circles’  nga miviřingo lí  ‘it’s not circles’

kijógojo  ‘bird (sp)’  nga kijógojo lí  ‘it’s not a bird’

kikálaargo  ‘pan’  nga kikálaargo lí  ‘it’s not a pan’

There are no words in Matuumbi which are toneless when said by themselves, thus ‘kitekeljo 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 an H tone on the second vowel depends on whether the word is said alone or is followed by another word, and those in (26), where the second vowel always has an H tone. The solution 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 an H at the end of an utterance by a rule that assigns an H tone to the second vowel of a toneless word which comes at the end of an utterance. Thus in the case of Matuumbi 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 itself: 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.

4.6 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)

<table>
<thead>
<tr>
<th>Simple</th>
<th>Perfective</th>
</tr>
</thead>
<tbody>
<tr>
<td>olo</td>
<td>oloia</td>
</tr>
<tr>
<td>lafo</td>
<td>lafoia</td>
</tr>
<tr>
<td>anja</td>
<td>anjaia</td>
</tr>
<tr>
<td>usu</td>
<td>usuia</td>
</tr>
<tr>
<td>tau</td>
<td>tauia</td>
</tr>
<tr>
<td>taui</td>
<td>tauia</td>
</tr>
<tr>
<td>sa:ili</td>
<td>sa:ilia</td>
</tr>
<tr>
<td>vanjaia</td>
<td>vanjaia</td>
</tr>
<tr>
<td>pa:i</td>
<td>pa:ia</td>
</tr>
<tr>
<td>naumati</td>
<td>naumatia</td>
</tr>
<tr>
<td>sa:uni</td>
<td>sa:unia</td>
</tr>
<tr>
<td>se:ji</td>
<td>se:ja</td>
</tr>
<tr>
<td>lele</td>
<td>lelea</td>
</tr>
<tr>
<td>su:e</td>
<td>su:ea</td>
</tr>
</tbody>
</table>
Examples such as oloia, aŋaia, and usua suggest that the perfective suffix is -ia, and the simple form of the verb reflects the underlying form of the root. Examples such as seji ~ sejia or lele ~ lele suggest a phonological rule, since the combination of the presumed stems seji and lele with the perfective affix -ia would result in the incorrect forms *sejia, *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**

\[
\begin{array}{c}
+\text{syl} \\
-\text{back}
\end{array}
\rightarrow \emptyset \quad \begin{array}{c}
+\text{syl} \\
-\text{back}
\end{array}
\]

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) \[ \emptyset \rightarrow \begin{array}{c}
+\text{syl} \\
+\text{high} \\
-\text{back}
\end{array} / \begin{array}{c}
+\text{syl} \\
+\text{back}
\end{array} [+\text{low}] \]

This latter rule is more complicated than (28). Additional data 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 stem 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.

<table>
<thead>
<tr>
<th>Simple</th>
<th>Perfective</th>
<th>Simple</th>
<th>Perfective</th>
</tr>
</thead>
<tbody>
<tr>
<td>tu:</td>
<td>tu:lia</td>
<td>au</td>
<td>aulia</td>
</tr>
<tr>
<td>tau</td>
<td>taulia</td>
<td>ma:tau</td>
<td>ma:taulia</td>
</tr>
<tr>
<td>?alo</td>
<td>?alofia</td>
<td>ili</td>
<td>ilifia</td>
</tr>
<tr>
<td>oso</td>
<td>osofia</td>
<td>ulu</td>
<td>ulufia</td>
</tr>
<tr>
<td>sao</td>
<td>saofia</td>
<td>taŋo</td>
<td>taŋofia</td>
</tr>
<tr>
<td>asu</td>
<td>asuŋia</td>
<td>soa</td>
<td>soaŋia</td>
</tr>
</tbody>
</table>

**Underlying representations**
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, s, t, m or ?, 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 ([uluia]), s ([tofui]), and s ([valusia]); and while f appears after o, so do f ([ifouia]), m ([naloma]), and s ([milosi]). 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’
taxul ‘cost’ ma:taul ‘observe’
?alof ‘avoid’ ilif ‘blow’
o sof ‘jump’ uluf ‘enter’
saof ‘collect’ ta?of ‘take hold’
asuŋ ‘smoke’ soaŋ ‘have a friend’
poleŋ ‘be anxious’ fesiliŋ ‘question’
ifoŋ ‘bow down’ ?oteŋ ‘scold’
ulaŋ ‘mock’ tofuŋ ‘dive’
milos ‘twist’ laʔas ‘step’
valus ‘scrape’ taŋis ‘cry’
velas ‘be cooked’ motus ‘break’
apit ‘be lodged’ mataʔutia ‘fear’
eʔet ‘be raised’ sautia ‘fall’
lava:t ‘be able’ oʔotia ‘arrive’
u:t ‘grip’ ufitia ‘cover’
punit ‘be blocked’ tanumia ‘cover up’
siʔom ‘be enclosed’ moʔomia ‘admire’
ŋalo ‘forget’ taomia ‘cover’
sopoʔia ‘go across’ fanaʔia ‘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

\[ C \rightarrow \emptyset / \_ # \]

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 underlyingly 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 form, or some other form. The underlying form of the word for ‘stand’ is /tuːl/. We learn that this is the underlying form by comparing the simple form [tuː] and the perfective [tuːlia] and understanding that the perfective form preserves important information about the underlying form that is lost in the simple form. But the perfective form itself is [tuːlia] – 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 actually surface as such in any form of a word. Consider the following examples:

(33) Present middle Future innovative Future conservative

madąŋəb dáŋbáll dáŋóbl ‘cover’
matéʔəb təʔábáll təʔíbl ‘pull out’
maŋetom ᵙatamáll ᶙatól ‘lick’
matábək tabokáll tabákl ‘patch’
maʔárm ?atamáll ?atóm ‘taste’
mosésəb sasobáll sasóbl ‘burn’

The prefix for the present middle is apparently /məl/, 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 of the word for ‘cover’ has three surface realizations: dąŋəb, dąŋəb, and dąŋəb. 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

\[
\begin{align*}
\text{[+syl]} & \rightarrow \text{[–high]} \\
\text{[–stress]} & \rightarrow \text{[–lo]} \\
 & \rightarrow \text{[+back]} \\
 & \rightarrow \text{[–rd]}
\end{align*}
\]

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 the word for ‘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 the word for ‘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 the word for ‘cover’ must be [o], since that is the realization which the vowel has when it is stressed, and the second vowel of the word for ‘pull out’ must be [i]. Thus, the underlying forms of the stems given above would be the following.

(35) daŋob ‘cover’ teʔib ‘pull out’
    ɲetom ‘lick’ tabak ‘patch’
    ?aram ‘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. There are many idiolectal differences in the pronunciation of certain words such as economy, where some people pronounce the word as [ij ’kanəmij] and others pronounce it as [ə ’kanəmij]: only attempt to account for the pronunciations given here.

(36) ’manətən  ’monətən’  ma ’natənij  ’monətəni’
      ’trələɡrəf  ’teɡləgrəf’  ta ’ləɡrəfi’  ’teɡləɡrəfi’
      ’epəɡrəf  ’epiɡrəf’  ə ’piɡrəfi’  ’epiɡrəfi’
      ’rələtəv  ’rələtəvi’  ra ’ləjən’  ’rələjəni’
      ə ’kanəmij  ’ekə ’nəmək  ’ekə ’nəmək’
      ’dijfəkt  ’defəkt (noun)  də ’frəktəv  ’defəktəv’
      ’dəməkrət  ’deməkrət’  də ’məkrəsi’  ’deməkrəsi’

ˈmanətən ˈmonətən’ ma’natənij ‘monətəni’
ˈtrələɡrəf ˈteɡləɡrəf’ ta’ləɡrəfi ‘teɡləɡrəfi’
ˈepəɡrəf ˈepiɡrəf’ ə ’piɡrəfi ‘epiɡrəfi’
ˈrələtəv ˈrələtəvi’ ra ’ləjən ‘rələjəni’
ə ’kanəmij  ’ekə ’nəmək ‘ekə ’nəmək’
ˈdijfəkt ˈdefəkt (noun) də ’frəktəv ‘defəktəv’
ˈdəməkrət ˈdeməkrət’ də ’məkrəsi ‘deməkrəsi’
As in Palauan, there is an alternation between stressed full vowel and unstressed schwa. We assume underlying stems with multiple full vowels, e.g. /manatown/, /ˈteləɡræf/, /ˈlɛŋɡræf/, /dəmækraet/, /ˈfownəlædə/, etc. But not every unstressed vowel is reduced: cf., for example, /ˈrelətɪv/, /ˈdɪfəkt, ˈmænətəʊm/ 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.** The following examples will illustrate the logic that leads to seeing the correct underlying forms, in explaining variations found in the verb root in Tonkawa (Texas). You must first give a morphological analysis of the data, identifying the morphemes for progressive, present, first-singular object, and third-plural object; you must also set forth initial hypotheses about the underlying forms of roots. The data to be accounted for are as follows.

(37)  picno?  ‘he cuts’  picnano?  ‘he is cutting’
      wepceno?  ‘he cuts them’  wepcenano?  ‘he is cutting them’
      kepcceno?  ‘he cuts me’  kepccenano?  ‘he is cutting me’
      notxo?  ‘he hoes’  notxonono?  ‘he is hoeing’
      wentoxo?  ‘he hoes them’  wentoxono?  ‘he is hoeing them’
      kentoxo?  ‘he hoes me’  kentoxono?  ‘he is hoeing me’
      netlo?  ‘he licks’  netleno?  ‘he is licking’
      wentalo?  ‘he licks them’  wentaleno?  ‘he is licking them’
      kentalo?  ‘he licks me’  kentalenono?  ‘he is licking me’
      naxco?  ‘he makes fire’  naxceno?  ‘he is making fire’
      wenxaco?  ‘he makes them fire’  wenxaceno?  ‘he is making them fire’
      kenxaco?  ‘he makes me fire’  kenxaceno?  ‘he is making me fire’
      jamxo?  ‘he paints a face’  jamxano?  ‘he is painting a face’
      wejmaxo?  ‘he paints their face’  wejemxano?  ‘he is painting their face’
      kejmaxo?  ‘he paints my face’  kejmaxano?  ‘he is painting my face’
      nawlo?  ‘he spreads’  nawleno?  ‘he is spreading’
      wenwelo?  ‘he spreads them’  wenweleno?  ‘he is spreading them’
      kenwelo?  ‘he spreads me’  kenweleno?  ‘he is spreading me’

Every word in this set ends with əʔ, and the verb forms have a third-person subject, suggesting that -əʔ marks third-person subject. Comparing the habitual present and present progressive form, we see that the present
progressive is marked by a suffix, -\(n\)- or \(-Vn\)- before the suffix \(-o\)\(?\). An object is marked by a prefix, \(we\)- for third-plural object and \(ke\)- for first-singular object. What remains is the verb root.

We have two unresolved questions: whether the suffix for the progressive is \(-n\)-, or is there a vowel in the suffix? and what is the underlying form of the verb root? To resolve the first question, we look at verbs with no object:

(38)  
\[
\begin{align*}
\text{picno?} & \quad \text{picnano?} \\
\text{notxo?} & \quad \text{notxono?} \\
\text{netlo?} & \quad \text{netleno?} \\
\text{naxco?} & \quad \text{naxceno?} \\
\text{jamxo?} & \quad \text{jamxano?} \\
\text{nawlo?} & \quad \text{nawleno?}
\end{align*}
\]

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. Clearly, the vowel before \(n\) ranges over \(a\), \(o\), and \(e\), and there is no reasonable way to predict which vowel is present. Since that information is governed by which root appears before the suffix, the vowel is part of the underlying form of the verb root. Thus we arrive at the following partial answer to the question about the underlying forms of the verb roots:

(39)  
\[
\begin{align*}
\text{/picna/} & \quad \text{‘cut’} \\
\text{/notxo/} & \quad \text{‘hoe’} \\
\text{/netle/} & \quad \text{‘lick’} \\
\text{/naxce/} & \quad \text{‘make a fire’} \\
\text{/jamxa/} & \quad \text{‘paint a face’} \\
\text{/nawle/} & \quad \text{‘spread’}
\end{align*}
\]

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

(40)  
\[
\begin{align*}
\text{Predicted form} & \quad \text{Actual surface form} \\
\text{picnao?} & \quad \text{picno?} & \quad \text{‘cut’} \\
\text{notxoo?} & \quad \text{notxo?} & \quad \text{‘hoe’} \\
\text{netleo?} & \quad \text{netlo?} & \quad \text{‘lick’} \\
\text{naxceo?} & \quad \text{naxco?} & \quad \text{‘make a fire’} \\
\text{jamxao?} & \quad \text{jamxzo?} & \quad \text{‘paint a face’} \\
\text{nawleo?} & \quad \text{nawlo?} & \quad \text{‘spread’}
\end{align*}
\]

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**

\[ V \rightarrow \emptyset / _V \]

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 prefix 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**

<table>
<thead>
<tr>
<th>Stem without prefix</th>
<th>Stem with CV prefix</th>
</tr>
</thead>
<tbody>
<tr>
<td>picna</td>
<td>pcena</td>
</tr>
<tr>
<td>notxo</td>
<td>ntoxo</td>
</tr>
<tr>
<td>netle</td>
<td>ntale</td>
</tr>
<tr>
<td>naxce</td>
<td>nxace</td>
</tr>
<tr>
<td>jamxa</td>
<td>jmaxa</td>
</tr>
<tr>
<td>nawle</td>
<td>nwele</td>
</tr>
</tbody>
</table>

In forms without a prefix, there is a vowel between the first two consonants and none between the second and third consonants; in forms 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 alternative is that this vowel is epenthetic (inserted); the other is that the vowel is part of the underlying vowel of the stem and is deleted in some phonological context. 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) | Stem with CV prefix |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>picena</td>
<td>‘cut’</td>
</tr>
<tr>
<td>notoxo</td>
<td>‘hoe’</td>
</tr>
<tr>
<td>netale</td>
<td>‘lick’</td>
</tr>
<tr>
<td>naxace</td>
<td>‘make a fire’</td>
</tr>
<tr>
<td>jamaxa</td>
<td>‘paint a face’</td>
</tr>
<tr>
<td>nawele</td>
<td>‘spread’</td>
</tr>
</tbody>
</table>

The underlying forms of prefixed and unprefixed forms would thus be as follows (illustrating with the progressive form of the verb):
Compare this with the surface form of the verbs:

(45) Unprefixed    Prefixed
    picnanoʔ  kepccenanoʔ 'cut'
    notxonoʔ  kentoxonoʔ 'hoe'
    netlenoʔ  kentalenoʔ 'lick'
    naxcenoʔ  kenxacenoʔ 'make a fire'
    jamxanoʔ  kejmaxanoʔ 'paint a face'
    nawnenoʔ  kenwelenoʔ 'spread'

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

(46) V → Ø / # 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 when it becomes clear that the initial hypothesis doesn’t work perfectly. Thus we began with the hypothesis that the underlying forms were /picna/, /notxol/, /netle/, and so on, and were able to account for a certain amount of data based on that hypothesis, but later modified our hypothesis about underlying forms to be /picenal/, /notoxol/, /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 analysis is that we always seek ways to test the predictions of our hypotheses. The hypothesis that the stems are underlying /picnal/, /notxol/, /netele/, 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 wepcenoʔ, wentoxoʔ, wentaloʔ and wenxacoʔ 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 we 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 realizations, 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 neutralizes 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’
- jaarato ‘black bee’ nojaaratoti ‘my black bee’
- kanari ‘wild turkey’ nojanariti ‘my wild turkey’
- kosiri ‘white monkey’ nojosiriti ‘my white monkey’
- pisiro ‘small toucan’ nowisiroti ‘my small toucan’
- porita ‘small hen’ noworitati ‘my small hen’

2 Xavante

What is the underlying form of the prefix meaning ‘your’? Formalize the rule which accounts for the change in that prefix.
3 Kuria I

What are the underlying forms of the prefixes marking the infinitive and the objects ‘you,’ ‘it (cl. 3)’ (which refers to one of the noun classes in the language)? Give a rule that explains the non-underlying pronunciation of the prefix. Tone can be ignored.

<table>
<thead>
<tr>
<th>‘to V’</th>
<th>‘to V you’</th>
<th>‘to V it (cl. 3)’</th>
</tr>
</thead>
<tbody>
<tr>
<td>okoréndá</td>
<td>ogokóreendá</td>
<td>okogóreendá</td>
</tr>
<tr>
<td>ogosóóká</td>
<td>okogosoóká</td>
<td>okogosoóká</td>
</tr>
<tr>
<td>ogoséékérá</td>
<td>okogóseekérá</td>
<td>okogóseekérá</td>
</tr>
<tr>
<td>ogotáangátá</td>
<td>okogótaangátá</td>
<td>okogótaangátá</td>
</tr>
<tr>
<td>ogotátíórá</td>
<td>okogótaíórá</td>
<td>okogótaíórá</td>
</tr>
<tr>
<td>okohéétóká</td>
<td>ogokóheétóká</td>
<td>okogóheétóká</td>
</tr>
<tr>
<td>ogokáráangéra</td>
<td>okogokáráangéra</td>
<td>okogokáráangéra</td>
</tr>
<tr>
<td>okobéémérá</td>
<td>ogokóbeémérá</td>
<td>okogóbeémérá</td>
</tr>
<tr>
<td>okogástá</td>
<td>ogokógástá</td>
<td>okogógástá</td>
</tr>
<tr>
<td>okomáŋa</td>
<td>ogokómáŋa</td>
<td>okokómáŋa</td>
</tr>
</tbody>
</table>

4 Korean

Give the underlying representations of each of the verb stems found below; state what phonological rule applies to these data. (There is a vowel harmony rule explaining the variation between final a and ā in the imperative, which you do not need to be concerned with.)

<table>
<thead>
<tr>
<th>Imperative</th>
<th>Conjunctive</th>
</tr>
</thead>
<tbody>
<tr>
<td>ip̂ə</td>
<td>ipk’o</td>
</tr>
<tr>
<td>kup̂ə</td>
<td>kupk’o</td>
</tr>
<tr>
<td>kapʰa</td>
<td>kapk’o</td>
</tr>
<tr>
<td>tlipʰo</td>
<td>tlpk’o</td>
</tr>
<tr>
<td>tata</td>
<td>tatk’o</td>
</tr>
<tr>
<td>putʰo</td>
<td>putk’o</td>
</tr>
<tr>
<td>makə</td>
<td>makk’o</td>
</tr>
<tr>
<td>t’ukə</td>
<td>t’ukk’o</td>
</tr>
<tr>
<td>ikə</td>
<td>ikk’o</td>
</tr>
<tr>
<td>tak’a</td>
<td>takk’o</td>
</tr>
<tr>
<td>k’ak’a</td>
<td>k’akk’o</td>
</tr>
<tr>
<td>sak’ə</td>
<td>sakk’o</td>
</tr>
</tbody>
</table>
5 Zoque

Provide the necessary phonological rules to describe the alternations found in the following data. Give the underlying representation for each noun stem and state what the underlying form of the morpheme meaning ‘my’ is.

<table>
<thead>
<tr>
<th>N</th>
<th>my N</th>
<th>N</th>
<th>my N</th>
</tr>
</thead>
<tbody>
<tr>
<td>waka</td>
<td>nwaka</td>
<td>‘basket’</td>
<td>huki</td>
</tr>
<tr>
<td>disko</td>
<td>ndisko</td>
<td>‘record’</td>
<td>jomo</td>
</tr>
<tr>
<td>buru</td>
<td>mburu</td>
<td>‘burro’</td>
<td>gaju</td>
</tr>
<tr>
<td>pama</td>
<td>mbama</td>
<td>‘clothes’</td>
<td>plato</td>
</tr>
<tr>
<td>kaju</td>
<td>ŋgaju</td>
<td>‘horse’</td>
<td>tṵrangoja</td>
</tr>
<tr>
<td>tatah</td>
<td>ndatah</td>
<td>‘father’</td>
<td>tṵima</td>
</tr>
<tr>
<td>faha</td>
<td>faha</td>
<td>‘belt’</td>
<td>sak</td>
</tr>
<tr>
<td>ḫapun ḫapun</td>
<td>‘soap’</td>
<td>lawus</td>
<td>lawus</td>
</tr>
</tbody>
</table>

6 Hungarian

Explain what phonological process affects consonants in the following data (a vowel harmony rule makes suffix vowels 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.

<table>
<thead>
<tr>
<th>Noun</th>
<th>In N</th>
<th>From N</th>
<th>To N</th>
</tr>
</thead>
<tbody>
<tr>
<td>kalap</td>
<td>kalapban</td>
<td>kalapto:l</td>
<td>kalapnak</td>
</tr>
<tr>
<td>ku:t</td>
<td>ku:dban</td>
<td>ku:ttö:l</td>
<td>ku:tnak</td>
</tr>
<tr>
<td>ṣa:k</td>
<td>ṣa:dban</td>
<td>ṣa:kto:l</td>
<td>ṣa:knak</td>
</tr>
<tr>
<td>re:s</td>
<td>re:dben</td>
<td>re:stö:l</td>
<td>re:snak</td>
</tr>
<tr>
<td>ḫioř</td>
<td>ḫiořban</td>
<td>ḫiořtö:l</td>
<td>ḫiořnak</td>
</tr>
<tr>
<td>ketret*</td>
<td>ketred*ben</td>
<td>ketret*to:l</td>
<td>ketret*nek</td>
</tr>
<tr>
<td>test</td>
<td>testben</td>
<td>testtö:l</td>
<td>testnak</td>
</tr>
<tr>
<td>rab</td>
<td>rabban</td>
<td>raptö:l</td>
<td>rbnak</td>
</tr>
<tr>
<td>ka:d</td>
<td>ka:dban</td>
<td>ka:ttö:l</td>
<td>ka:dnak</td>
</tr>
<tr>
<td>meleg</td>
<td>melegben</td>
<td>melegtö:l</td>
<td>melegnek</td>
</tr>
<tr>
<td>vi:z</td>
<td>vi:zben</td>
<td>vi:zto:l</td>
<td>vi:znak</td>
</tr>
<tr>
<td>a:ɡ</td>
<td>a:ɡban</td>
<td>a:ktö:l</td>
<td>a:ɡnak</td>
</tr>
<tr>
<td>sem</td>
<td>semben</td>
<td>semtö:l</td>
<td>semnek</td>
</tr>
<tr>
<td>byn</td>
<td>bynben</td>
<td>byntö:l</td>
<td>bynnek</td>
</tr>
<tr>
<td>toroɲ</td>
<td>toroɲban</td>
<td>toroɲtö:l</td>
<td>toroɲnak</td>
</tr>
<tr>
<td>fal</td>
<td>falban</td>
<td>faltö:l</td>
<td>falknak</td>
</tr>
<tr>
<td>ø:r</td>
<td>ø:rben</td>
<td>ø:rne:lo</td>
<td>ø:rnek</td>
</tr>
<tr>
<td>saj</td>
<td>sajban</td>
<td>sajto:l</td>
<td>sajnak</td>
</tr>
</tbody>
</table>

7 Kuria II

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

<table>
<thead>
<tr>
<th>Verb</th>
<th>Verb for</th>
</tr>
</thead>
<tbody>
<tr>
<td>suraanga</td>
<td>suraangera</td>
</tr>
<tr>
<td>taŋgata</td>
<td>taŋgatera</td>
</tr>
<tr>
<td>baamba</td>
<td>baambera</td>
</tr>
</tbody>
</table>
8 Isthmus Zapotec

Provide an analysis of the following alternations, formalizing your rules using features and listing the underlying forms of all morphemes.

<table>
<thead>
<tr>
<th>N</th>
<th>his N</th>
<th>sg</th>
<th>pl</th>
<th>sg</th>
<th>pl</th>
</tr>
</thead>
<tbody>
<tr>
<td>pan</td>
<td>jpanbe</td>
<td>reenda</td>
<td>‘guard’</td>
<td>rema</td>
<td>‘cultivate’</td>
</tr>
<tr>
<td>taburete</td>
<td>jtaburetebe</td>
<td>hoora</td>
<td>‘thresh’</td>
<td>sooka</td>
<td>‘respect’</td>
</tr>
<tr>
<td>tanguju</td>
<td>jtangujube</td>
<td>roma</td>
<td>‘bite’</td>
<td>tat’ora</td>
<td>‘tear’</td>
</tr>
<tr>
<td>kuba</td>
<td>jkubabe</td>
<td>siika</td>
<td>‘close’</td>
<td>tiga</td>
<td>‘leave behind’</td>
</tr>
<tr>
<td>luuna?</td>
<td>hiuunabe</td>
<td>ruga</td>
<td>‘cook’</td>
<td>suka</td>
<td>‘plait’</td>
</tr>
<tr>
<td>neza</td>
<td>hnezabe</td>
<td>suka</td>
<td>‘plait’</td>
<td>huuta</td>
<td>‘‘blow’’</td>
</tr>
<tr>
<td>mani?</td>
<td>hmanibe</td>
<td>hootera</td>
<td>‘‘blow’’</td>
<td>ringa</td>
<td>‘‘fold’’</td>
</tr>
<tr>
<td>diid’a?</td>
<td>jtiid’abe</td>
<td>seinda</td>
<td>‘‘win’’</td>
<td>siinda</td>
<td>‘‘win’’</td>
</tr>
</tbody>
</table>

9 Lezgian

Give underlying forms of all morphemes and formalize the rules which account for the following data:

<table>
<thead>
<tr>
<th>sg</th>
<th>pl</th>
<th>sg</th>
<th>pl</th>
</tr>
</thead>
<tbody>
<tr>
<td>tar</td>
<td>tarar</td>
<td>‘tree’</td>
<td>peler</td>
</tr>
<tr>
<td>q’el</td>
<td>q’eler</td>
<td>‘salt’</td>
<td>qawar</td>
</tr>
<tr>
<td>wyl</td>
<td>wyler</td>
<td>‘husband’</td>
<td>luwar</td>
</tr>
<tr>
<td>lif</td>
<td>lifer</td>
<td>‘pigeon’</td>
<td>t’ur</td>
</tr>
<tr>
<td>qyl</td>
<td>qyler</td>
<td>‘wheat’</td>
<td>bulut</td>
</tr>
<tr>
<td>k’at’arh</td>
<td>k’at’ar</td>
<td>‘foot’</td>
<td>tark’</td>
</tr>
<tr>
<td>mark’wh</td>
<td>mark’whar</td>
<td>‘stack’</td>
<td>rang</td>
</tr>
<tr>
<td>fend</td>
<td>fender</td>
<td>‘trick’</td>
<td>k’alub</td>
</tr>
<tr>
<td>k’arab</td>
<td>k’arabar</td>
<td>‘bone’</td>
<td>p’eleeng</td>
</tr>
<tr>
<td>qejd</td>
<td>qejer</td>
<td>‘remark’</td>
<td>rab</td>
</tr>
</tbody>
</table>
Give the underlying representations of the following nouns, and formalize the phonological rule which applies in the following data:

<table>
<thead>
<tr>
<th>nom sg</th>
<th>gen pl</th>
</tr>
</thead>
<tbody>
<tr>
<td>kubu</td>
<td>kubude</td>
</tr>
<tr>
<td>tiba</td>
<td>tibade</td>
</tr>
<tr>
<td>sadu</td>
<td>sadude</td>
</tr>
<tr>
<td>labu</td>
<td>labude</td>
</tr>
<tr>
<td>abi</td>
<td>abide</td>
</tr>
<tr>
<td>soga</td>
<td>sogade</td>
</tr>
<tr>
<td>nibu</td>
<td>nibude</td>
</tr>
<tr>
<td>kivi</td>
<td>kivide</td>
</tr>
<tr>
<td>lugu</td>
<td>lugude</td>
</tr>
<tr>
<td>saba</td>
<td>sabade</td>
</tr>
<tr>
<td>sula</td>
<td>sulade</td>
</tr>
<tr>
<td>tade</td>
<td>tadede</td>
</tr>
<tr>
<td>kude</td>
<td>kudede</td>
</tr>
<tr>
<td>viht</td>
<td>vihtade</td>
</tr>
<tr>
<td>vakk</td>
<td>vakkade</td>
</tr>
<tr>
<td>arg</td>
<td>argade</td>
</tr>
<tr>
<td>völg</td>
<td>völgabe</td>
</tr>
<tr>
<td>saøt</td>
<td>saøtade</td>
</tr>
<tr>
<td>mets</td>
<td>metsade</td>
</tr>
<tr>
<td>laisk</td>
<td>laiskade</td>
</tr>
<tr>
<td>hoob</td>
<td>hoobade</td>
</tr>
<tr>
<td>haav</td>
<td>haavade</td>
</tr>
<tr>
<td>lill</td>
<td>lilléde</td>
</tr>
<tr>
<td>kɔrb</td>
<td>kɔrbede</td>
</tr>
<tr>
<td>laht</td>
<td>lahtede</td>
</tr>
<tr>
<td>neem</td>
<td>neemede</td>
</tr>
<tr>
<td>leep</td>
<td>leepede</td>
</tr>
<tr>
<td>luik</td>
<td>luikede</td>
</tr>
<tr>
<td>jælɡ</td>
<td>jælɡede</td>
</tr>
<tr>
<td>kaart</td>
<td>kaartide</td>
</tr>
<tr>
<td>kɔrb</td>
<td>kɔrbide</td>
</tr>
<tr>
<td>paar</td>
<td>paaride</td>
</tr>
<tr>
<td>kook</td>
<td>kookide</td>
</tr>
<tr>
<td>kepp</td>
<td>keppide</td>
</tr>
<tr>
<td>pyks</td>
<td>pykside</td>
</tr>
</tbody>
</table>
11 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?

<table>
<thead>
<tr>
<th>Digit</th>
<th>Underlying Form</th>
<th>Underlying Form</th>
<th>Underlying Form</th>
<th>Underlying Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>dʒ̥u</td>
<td>dʒ̥ig</td>
<td>dʒ̥ugdʒ̥ig</td>
<td>'11'</td>
</tr>
<tr>
<td>14</td>
<td>ʃ̥i</td>
<td>ʃ̥iub̥i</td>
<td>ʃ̥iub̥i</td>
<td>'14'</td>
</tr>
<tr>
<td>19</td>
<td>ʃ̥ugu</td>
<td>ʃ̥ugu</td>
<td>ʃ̥ugu</td>
<td>'19'</td>
</tr>
<tr>
<td>50</td>
<td>ŋ̥a</td>
<td>ŋ̥a</td>
<td>ŋ̥a</td>
<td>'50'</td>
</tr>
</tbody>
</table>

12 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.

**Nomination sg**

<table>
<thead>
<tr>
<th>Word</th>
<th>Underlying Form</th>
<th>Underlying Form</th>
<th>Underlying Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>varit</td>
<td>varihin</td>
<td>'2-year-old reindeer buck'</td>
<td></td>
</tr>
<tr>
<td>oahpis</td>
<td>oahpisin</td>
<td>'acquaintance'</td>
<td></td>
</tr>
<tr>
<td>tʃ̥oarvvuʃ̥</td>
<td>tʃ̥oarvvuʃ̥in</td>
<td>'antlers and skullcap'</td>
<td></td>
</tr>
<tr>
<td>lottæ:f</td>
<td>lottæ:dʒ̥in</td>
<td>'small bird'</td>
<td></td>
</tr>
<tr>
<td>tʃ̥uojvat</td>
<td>tʃ̥uojvagin</td>
<td>'yellow-brown reindeer'</td>
<td></td>
</tr>
<tr>
<td>ahhkut</td>
<td>ahhkubin</td>
<td>'grandchild of woman'</td>
<td></td>
</tr>
<tr>
<td>suohkat</td>
<td>suohkaœin</td>
<td>'thick'</td>
<td></td>
</tr>
<tr>
<td>heedøʃ̥</td>
<td>heedødʒ̥in</td>
<td>'poor guy'</td>
<td></td>
</tr>
<tr>
<td>æːddøut</td>
<td>æːddøubin</td>
<td>'grandchild of man'</td>
<td></td>
</tr>
<tr>
<td>bissobeæht:et</td>
<td>bissobeæht:ehin</td>
<td>'butt of gun'</td>
<td></td>
</tr>
<tr>
<td>tʃ̥eæht:it</td>
<td>tʃ̥eæht:ibin</td>
<td>'children of elder brother of man'</td>
<td></td>
</tr>
<tr>
<td>jæːmin</td>
<td>jæː:mimin</td>
<td>'death'</td>
<td></td>
</tr>
<tr>
<td>læːgeʃ̥</td>
<td>læː:gedʒ̥in</td>
<td>'mountain birch'</td>
<td></td>
</tr>
<tr>
<td>gaḥpiɾ</td>
<td>gaḥpiɾin</td>
<td>'cap'</td>
<td></td>
</tr>
<tr>
<td>gaːwhtis</td>
<td>gaː:whtis:in</td>
<td>'8 people'</td>
<td></td>
</tr>
<tr>
<td>æːslat</td>
<td>æː:slagin</td>
<td>[man's name]</td>
<td></td>
</tr>
<tr>
<td>baːooʃ̥gæːtt:et</td>
<td>baːooʃ̥gæːtt:ebin</td>
<td>'tailed tit'</td>
<td></td>
</tr>
<tr>
<td>ahhkit</td>
<td>ahhkiːibin</td>
<td>'boring'</td>
<td></td>
</tr>
<tr>
<td>bahaːnæːlat</td>
<td>bahaː:næːlagin</td>
<td>'badly behaved'</td>
<td></td>
</tr>
<tr>
<td>bɛʃʃtor</td>
<td>bɛʃʃtorin</td>
<td>'bird type'</td>
<td></td>
</tr>
<tr>
<td>heevemæahtun</td>
<td>heevemæahtunin</td>
<td>'inappropriate'</td>
<td></td>
</tr>
<tr>
<td>bejooʃt</td>
<td>bejooʃhin</td>
<td>'white reindeer'</td>
<td></td>
</tr>
<tr>
<td>bissomeahtun</td>
<td>bissomeahtumin</td>
<td>'unstable'</td>
<td></td>
</tr>
<tr>
<td>laðæːs</td>
<td>laðæːːsin</td>
<td>‘something jointed’</td>
<td></td>
</tr>
<tr>
<td>----------------</td>
<td>-----------------</td>
<td>---------------------</td>
<td></td>
</tr>
<tr>
<td>heaijusmelat</td>
<td>heaijusmelagin</td>
<td>‘unhappy’</td>
<td></td>
</tr>
<tr>
<td>heaŋkkan</td>
<td>heaŋkkanin</td>
<td>‘hanger’</td>
<td></td>
</tr>
<tr>
<td>jamaːːn</td>
<td>jamaːːnin</td>
<td>‘something that makes noise’</td>
<td></td>
</tr>
</tbody>
</table>

**Further reading**
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, a seemingly complex set of alternations can be given a simple explanation if you separate the effect of different rules which may 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.

5.1 Separating the effects of different rules

Very often, when you analyze phonological alternations, insights into the nature of these alternations are revealed once you realize that a word may be subject to more than one rule, each of which can affect the same segment. You should not think of a phonology as being just a collection of direct statements of the relation between underlying segments and their surface realization. Such a description is likely to be confusing and complex, and will miss a number of important generalizations. Look for ways to decompose a problem into separate, smaller, and independent parts, stated in terms of simple and general rules. The different effects which these rules can have on a segment may accumulate, to give a seemingly complex pattern of phonetic change.

5.1.1 Votic: palatalization and raising/fronting

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

(1) a. Nominative      Partitive
    vɔrrko          vɔrrkoa         ‘net’
    t’ako           t’aka          ‘cuckoo’
    lintu           lintua         ‘bird’
    saatu           saatuia        ‘garden’
    jalka           jalkaa         ‘foot’
    bot’ka          bot’kaa        ‘barrel’
    einæ            einææ          ‘hay’
    vævy            vævyæ          ‘son-in-law’

    b. siili          siiliæ         ‘hedgehog’
    lusti            lustia         ‘pretty’

    c. jarvi          jarvæa        ‘lake’
    mæt’i           mæt’ææ        ‘hill’
    t’iwi           t’iveæ         ‘stone’

    d. kurt’i        kurkœa         ‘stork’
    ɔl’i           ɔlkœa          ‘straw’
    kaht’i         kahkœa         ‘birch’
The first group of examples (1a) shows 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 skips over the vowel [i], but if there are no vowels other than [i] preceding, the harmony rule turns the suffix vowel into a front vowel). The second group of examples (1b) illustrates 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 ǝ become [i] word-finally.

(2) Final Fronting/Raising

\[
\begin{array}{c}
\text{+syl} \\
\text{-rd} \\
\text{-lo}
\end{array} \to \left[ \begin{array}{c}
\text{+high} \\
\text{-back}
\end{array} \right] / \_ \_ #
\]

The essential difference between the examples of (1b) and (1c) is that the forms in (1b) underly end in the vowel /i/, and those in (1c) end in /e/ or /ǝ/. In the last set of examples (1d), the noun root underly end in the sequence /kǝ/, which can be seen directly in kurkǝ-ǝ. However, the final CV of the root appears as [tʃi] in the nominative kurtʃi.

It would be unrevealing to posit a rule changing word-final /kǝ#/ into [tʃi] in one step. A 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. You may not know at this point that such a rule is not found in other languages – part of learning about phonology is learning what processes do exist in languages, something you will have a better basis for judging by the end of this book. What you can see right now is that such a rule treats it as a coincidence that the underlying final schwa actually becomes [i] on the surface by an independently necessary rule, so that much of the supposed rule applying to /kǝ#/ is not actually specific to /kǝ#/

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 /kǝ/ 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

\[
\begin{array}{c}
\text{+cons} \\
\text{+back}
\end{array} \to \left[ \begin{array}{c}
\text{+cor} \\
\text{-syl}
\end{array} \right] / \_ \_ \_ \_ #
\]

We can thus account for the change of underlying /kurkǝ/ and /slkǝ/ to [kurtʃi] and [sltʃi] 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 occurrences of the vowel [i], and those derived cases of [i] condition the application of palatalization.

(4) \[\text{kurko/} \quad \text{underlying} \]
    \[\text{kurki} \quad \text{vowel raising} \]
    \[\text{kurt'î} \quad \text{palatalization} \]

You should take note of two points regarding how the palatalization rule is formalized. First, by strictly making a velar consonant become [+cor], the result would be a velarized retroflex stop \[\text{ʈ}'\]: such sounds simply do not exist in the language, in fact the [-ant] coronal sounds of the language are all alveopalatal, and the alveopalatal stops in Votic are all affricates. Observed \[\text{ʈ}'\] is the closest segment of the language to \[\text{ʈ}'\].

Second, we do not have direct evidence that all front vowels trigger the change of velars, in fact we only have direct evidence that word-final [i] triggers the change. At the same time, we do not have any direct evidence that it matters whether the triggering vowel is word-final or not, nor do we have any evidence that the other front vowels [y ø e æ] fail to trigger the change. Because there is no evidence for adding restrictions to the rule, we follow the general scientific principle of stating the rule as simply as possible, consistent with the data.

5.1.2 Kamba: palatalization and glide formation

There is a phonological process in Kamba (Kenya) whereby the combination of a velar consonant plus the glide \[j\] fuses into an alveopalatal affricate. This can be seen in (5), 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 we can see the causative of the same verb, which is formed by suffixing \[-j\] after the verb root before the inflectional marker -a.

(5) to V to cause to V
a. kokâmâ kokâmjâ ‘milk’
kokonà kokonjâ ‘hit’
kolaâambà kolâambjâ ‘lap’
kotâlâ kotâljâ ‘count’
kwaambatâ kwaambatjâ ‘go up’
kwaâdâ kwaâdjâ ‘govern’
kweëtâ kwëëtjâ ‘answer’
kwiëmbâ kwïmbjâ ‘swell’
b. kojâikâ kojîtâ ‘arrive’
kojâloka kojâlotjâ ‘fall’
koli kä koliitâ ‘enter’
kolëngâ kolëndjâ ‘aim’
The examples in (a) illustrate the causative affix following various non-velar consonants of the language. In (b), we see the causative of various roots which end in k or g, where by analogy to the data in (a) we predict the causatives /koβikjà/, /koβálokjà/, /koβëŋgjà/, and so on. Instead of the expected consonant sequences kj, gj, we find instead that the velar consonant has been replaced by an alveopalatal affricate, due to the following rule:

\( \text{(6) Palatalization} \)

\[
\begin{array}{c}
\text{[+cons]} \\
\text{[+back]} \\
\text{[+syl]} \\
\text{[-cons]} \\
\text{[-back]}
\end{array} \rightarrow [\text{[+cor]} \emptyset]
\]

Examples of glide formation are also seen in (5), where the vowel /o/ in the infinitive prefix becomes [w] before another vowel. This process of glide formation is further illustrated in (7) and (8). In (7), you 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 (Kamba nouns have a dozen grammatical agreement classes, analogous to gender in some European languages).

When the verb root begins with a vowel, we would predict a sequence of vowels such as "koasja" for 'to lose,' in lieu of a rule modifying vowel sequences. Vowel sequences are avoided in Kamba by the application of the rule of glide formation, according to which any nonlow vowel becomes a glide before another vowel.

\( \text{(8) to V to V it (cl 3) to V them (cl 4) to V it (cl 7)} \)

\[
\begin{array}{l}
wáasja \quad \text{kowáasjà} \quad \text{komjáasjà} \quad \text{kot'áasjà} \quad \text{‘lose’} \\
wáákà \quad \text{komwáákà} \quad \text{komjáákà} \quad \text{kot'áákà} \quad \text{‘build’} \\
wáasá \quad \text{komwáásá} \quad \text{komjáásá} \quad \text{kot'áásá} \quad \text{‘carve’} \\
kómbá \quad \text{komómbá} \quad \text{komjómbá} \quad \text{kot'ómbá} \quad \text{‘mold’} \\
kookeljá \quad \text{komóokejá} \quad \text{komjóokejá} \quad \text{kot'óokejá} \quad \text{‘lift’} \\
kúúnà \quad \text{komúúnà} \quad \text{komjúúnà} \quad \text{kot'úúnà} \quad \text{‘fetch’}
\end{array}
\]
The Glide Formation rule can be formalized as (9).

(9) Glide Formation

\[ [+\text{syl}] \rightarrow [-\text{syl}] / \_ \_ V \]

While this rule does not explicitly state that the resulting glide is [+high], that value is predictable via structure preservation, given the fact that the language does not have glides that are [-high].

This rule would be expected to apply to underlying forms such as /kouna/ ‘to fetch’ and /ko-omba/ ‘to mold,’ since those forms have an underlying sequence of a vowel /o/ followed by another vowel. Applying that rule would result in [kw\_\_na] and [kw\_\_mba], but these are not the correct forms. We can resolve this problem once we observe that the glide [w] never appears before the tense round vowels [u, o] (but it can appear before the vowel [\_\_a], as seen in [kw\_\_na] ‘to see’ from /ko-\_na/).

It does not help to restrict rule (9) 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 [komj\_okelja] ‘to lift them’ and /ko-m\_\_n\_a/ becomes [komj\_\_n\_a] ‘to fetch them’). What seems to be a restriction on glide formation is highly specific: the tense 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, therefore we can’t just rewrite (9) so that it doesn’t apply before [u, o], since that would give [ko\_n\_a] and [ko\_mb\_a]. 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 on which vowels trigger the rule, and derive the intermediate forms kw\_\_na and kw\_\_mba. Since we have observed that the surface sequences [wo] and [wu] are 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.

(10) Glide Deletion

\[
\begin{align*}
[-\text{syl}] & \rightarrow \emptyset | \_ \_ +\text{round} \\
[+\text{round}] & \rightarrow \emptyset | \_ \_ +\text{tense}
\end{align*}
\]

Glide Formation first creates a glide, and some of the glides so created are then deleted by (10).
Another crucial rule interaction which we observe in (8) is between Glide Formation and Palatalization. As we have seen, Palatalization specifically applies to kj and gj, and Glide Formation creates glides from vowels, which can trigger application of Palatalization. This is shown in the derivation of [koʃa] from /ko-ké-aʃja/.

Thus Glide Formation creates phonological structures which are crucially referenced by other phonological rules.

5.1.3 Bukusu: nasal+consonant combinations

The theme which we have been developing in this chapter is that phonological grammars are composed of simple rule elements that interact in ways that make the data patterns appear complicated, and 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 glide formation and palatalization in Kamba, the phonological processes have been sufficiently different that no one would have problems seeing that these are different rules. A language may have phonological changes which seem similar in nature, or which apply in similar 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 (Kenya), where a number of changes affect sequences of nasal plus consonant.

Nasal Place Assimilation and Post-Nasal Voicing. In the first set of examples in (12), a voicing rule makes all underlyingly voiceless consonants voiced when preceded by a nasal, in this case after the prefix for the first-singular 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 third-plural prefix βa-, or when there is no prefix as in the imperative.

(12) Imperative 3pl pres 1sg pres
  t'a  βat'a  jdl'a  ‘go’
  te'xa  βat''exa  jdl'exa  ‘laugh’
  t'ul't'unga  βat'ul't'unga  jdl'ut'uunga  ‘sieve’
  talaanda  βataalaanda  ndalaanda  ‘go around’
  teexa  βateexa  ndeexa  ‘cook’
  tiira  βatiira  ndiira  ‘get ahold of’
  piima  βapiima  mbiima  ‘weigh’
  pakala  βapakala  mbakala  ‘writhe in pain’
  ketulula  βaketulula  ngetulula  ‘pour out’
  kona  βakona  ngona  ‘pass the night’
  kula  βakula  ngula  ‘buy’
  kwa  βakwa  ngwa  ‘fall’

We can state this voicing rule as follows.
You will also note that a nasal consonant always agrees in place of articulation with the following consonant, due to the following rule.

\[
\text{Post-Nasal Voicing} \quad [-\text{voice}] \rightarrow [+\text{voice}] / [+\text{nasal}] \\
\]

The data considered so far have not given clear evidence as to what the underlying place of articulation of the first-singular 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 underlingly begin with a vowel, where there is no assimilation. In the imperative, where no prefix precedes the stem, the glide [j] is inserted before the initial vowel. (The data in (17) include examples of underlying initial /j/, which is generally retained, showing that there cannot be a rule of j-deletion.) When the third-plural prefix /\beta/ precedes the stem, the resulting vowel sequence is simplified to a single non-high vowel. No rules apply to the first-singular prefix, which we can see surfaces as [n] before all vowels.

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.

\[
\text{Post-Nasal Hardening.} \quad \text{Another process of consonant hardening turns voiced continuants into stops after a nasal: } l \text{ and } r \text{ become } d, \beta \text{ becomes } b, \text{ and } j \text{ becomes } d^{p}.
\]
These data can be accounted for by the following rule:

(18)  **Post-Nasal Hardening**

\[ [+\text{voice}] \rightarrow [-\text{cont}] / [+\text{nasal}] \]

This formalization exploits the concept of structure preservation to account for the changes to /r, l, j/. By becoming [-cont], a change to [-son] is necessitated since there are no oral sonorant stops in Bukusu. Likewise the lack of lateral stops in the language means that /l/ becomes [-lat] when it becomes [-cont]. Since there is no segment [j] in Bukusu, making /j/ become a stop entails a change in place of articulation from palatal to alveopalatal, and from plain stop to affricate.

The generalizations expressed in rules (13) and (18) can be unified into one even simpler rule, which states that consonants after nasals become voiced stops.

(19)  **Post-Nasal Voicing-Hardening**

\[ C \rightarrow \begin{cases} 
  [+\text{voice}] \\
  [-\text{cont}] \\
  / [+\text{nasal}] 
\end{cases} \]

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

(20)  **Imperative**  

<table>
<thead>
<tr>
<th>3pl pres</th>
<th>1sg pres</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>tima</td>
<td>bätima</td>
<td>ndima</td>
</tr>
<tr>
<td>taanja</td>
<td>bataanja</td>
<td>ndaanja</td>
</tr>
<tr>
<td>tiiña</td>
<td>batiinja</td>
<td>ndiiña</td>
</tr>
</tbody>
</table>
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 (17), 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 (20a) is that although underlying /l/, /l/, and /l/ all become [d] after a nasal, the deletion of an underlying consonant in the environment N_VN only affects underlying /l/. Since the voicing-hardening rule (19) neutralizes the distinction between the three consonants after a nasal but in fact /l/ acts differently from /l/ and /l/ in the context N_VN, we can conclude that there is a prior rule deleting /l/ – but not /l/ or /l/ – in this context.

(21) l-deletion

\+[lat] \rightarrow \emptyset / [+nasal] \_ V_o / [+nasal]

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/. When (19) 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] versus [ndiina].

On the other hand, if you 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 ordering the rules so that l-deletion comes first, the distinction between /l/, which deletes, and /l/, which does not delete, is preserved.

Nasal Cluster Simplification. 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.

(22) Imperative 3pl pres 1sg pres

<table>
<thead>
<tr>
<th></th>
<th>3pl pres</th>
<th>1sg pres</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>mala</td>
<td>ßamala</td>
<td>mala</td>
<td>‘finish’</td>
</tr>
<tr>
<td>mapa</td>
<td>ßamaña</td>
<td>mapa</td>
<td>‘know’</td>
</tr>
<tr>
<td>meela</td>
<td>ßameela</td>
<td>meela</td>
<td>‘get drunk’</td>
</tr>
<tr>
<td>ñoola</td>
<td>ßanoola</td>
<td>ñoola</td>
<td>‘see into the spirit world’</td>
</tr>
</tbody>
</table>
In the case of *mala* ‘I finish,’ the underlying form would be /n-mala/ which would undergo the place assimilation rule (14), resulting in *mmala*. According to the data available to us, there are no sequences of nasals in the language, so it is reasonable to posit the following rule.

(23) **Nasal Cluster Simplification**

\[ [+\text{nas}] \rightarrow \emptyset / _{+\text{nas}} \]

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

(24) **Imperative** 3pl pres 1sg pres

<table>
<thead>
<tr>
<th></th>
<th>βa</th>
<th>na</th>
<th>‘defecate’</th>
</tr>
</thead>
<tbody>
<tr>
<td>naapa</td>
<td>βaβaanap</td>
<td>naaapa</td>
<td>‘chew’</td>
</tr>
<tr>
<td>nwa</td>
<td>βaanwa</td>
<td>nwa</td>
<td>‘drink’</td>
</tr>
</tbody>
</table>

The underlying form of *fuma* ‘I spread’ is /n-fuma/ since the prefix for 1sg is /n-/ and the root is /fuma/, and this contains a sequence nasal plus voiceless fricative. Our data indicate that this sequence does not appear anywhere in the language, so we may presume that such sequences are eliminated by a rule of nasal deletion. The formulation in (25) accounts for the deletion facts of (24).

(25) **Nasal Deletion**

\[ [+\text{nas}] \rightarrow \emptyset / _{-\text{voice}} \]

There can be an important connection between how rules are formulated and how they are ordered. In the analysis presented here, we posited the rules Nasal Deletion (25) and Post-Nasal Voicing-Hardening (19), repeated here, where Nasal Deletion applies first.

(19) **Post-Nasal Voicing-Hardening**

\[ C \rightarrow \left[ +\text{voice} \right] / _{-\text{cont}} / _{+\text{nas}} \]
Since, according to (25), only voiceless continuants trigger deletion of a following nasal, we do not expect /n-βala/ ‘I count’ to lose its nasal. However, there is the possibility that (19) could apply to /n-fwa/ ‘I die,’ since (19) does not put any conditions on the kind of consonant that becomes a voiced stop – but clearly, /f/ does not become a voiced stop in the surface form [fwa]. This is because Nasal Deletion first eliminates the nasal in /n-fwa/, before (19) has a chance to apply, and once the nasal is deleted, (19) can no longer apply.

You might consider eliminating the specification [−voice] from the formalization of (25) on the grounds that voiced continuants become stops by (19), so perhaps by applying (19) first, we could simplify (25). Such a reordering would fail, though, since (19) would not only correctly change /n-βala/ to [mbala], but would incorrectly change /n-fwa/ to *[mbwa]. The only way to eliminate the specification [−voice] in (25) would be to split (19) into two rules specifically applying to voiced continuants and voiceless stops – a considerable complication that negates the advantage of simplifying (25) by one feature specification.

**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.

(25) **Nasal Deletion**

\[ [+\text{nasal}] \rightarrow \emptyset /_\ [-\text{voice}] [+\text{cont}] \]

(14) **Nasal Place Assimilation**

\[ [+\text{nas}] \rightarrow [\alpha^\text{ant}] [\beta^\text{cor}] /_\ [+\text{syl}] [\alpha^\text{ant}] [\beta^\text{cor}] \]

(21) **l-Deletion**

\[ [+\text{lat}] \rightarrow \emptyset / [+\text{nasal}] \_ V_0 [+\text{nasal}] \]

(19) **Post-Nasal Voicing-Hardening**

\[ C \rightarrow [+\text{voice}] / [+\text{nas}] \_ \]

(23) **Nasal Cluster Simplification**

\[ [+\text{nas}] \rightarrow \emptyset /_\ [+\text{nas}] \]

Despite some similarity in these processes, which involve a common environment of nasal-plus-consonant, there is no reasonable way to state these processes as one 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.

### 5.1.4 Matuumbi

The following data from Matuumbi 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). You should be able to discern and formalize the rule that applies in these data, and order those rules correctly. What rule applies in the following data?

<table>
<thead>
<tr>
<th>Class</th>
<th>C-initial noun</th>
<th>V-initial noun</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>mi-kaáte</td>
<td>mj-oótó</td>
</tr>
<tr>
<td>5</td>
<td>li-kujuúnda</td>
<td>lj-oowá</td>
</tr>
<tr>
<td>7</td>
<td>ki-kálaango</td>
<td>kj-uúlá</td>
</tr>
<tr>
<td>8</td>
<td>i-kálaango</td>
<td>j-uúlá</td>
</tr>
<tr>
<td>14</td>
<td>u-tópe</td>
<td>w-uimbí</td>
</tr>
<tr>
<td>11</td>
<td>lu-toóndwa</td>
<td>lw-aaté</td>
</tr>
<tr>
<td>13</td>
<td>tu-tóópé</td>
<td>tw-aána</td>
</tr>
<tr>
<td>15</td>
<td>ku-suúle</td>
<td>kw-iisíwá</td>
</tr>
<tr>
<td>16</td>
<td>mu-kíkú</td>
<td>mw-iikú</td>
</tr>
</tbody>
</table>

The examples in (27) illustrate three rules. First, there is an optional rule applying in both subsets of (27) which deletes u after m, hence in these words, the prefix /mu/ can be pronounced in two ways, one with u and one without u. You should formalize the optional vowel deletion rule illustrated by these data.

An independent rule assimilates a nasal to the place of articulation of the following consonant (we saw this rule in previous Matuumbi data in chapters 2 and 4). This rule applies in both subsets of examples, and is the only other rule besides deletion of u involved in the first subset. The third rule applies in the second subset of examples, and explains the change in the initial consonant of the stem. This rule only applies to a glide preceded by a nasal which is separated by a morpheme boundary, notated in rules as “+.”

<table>
<thead>
<tr>
<th>Unreduced form</th>
<th>Reduced form</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. mu-tola . .</td>
<td>n-tola . .</td>
</tr>
<tr>
<td>mu-kálaangite</td>
<td>n-kálaangite</td>
</tr>
<tr>
<td>mu-pimé</td>
<td>m-pimé</td>
</tr>
<tr>
<td>b. mu-wesa . .</td>
<td>n-ŋ’esa . .</td>
</tr>
<tr>
<td>mu-jikitiile</td>
<td>n-jikitiile</td>
</tr>
<tr>
<td>mu-wuúngo</td>
<td>n-ŋ’uúngo</td>
</tr>
<tr>
<td>mu-juana</td>
<td>n-juana</td>
</tr>
</tbody>
</table>
An alternative transcription of these second set of forms would be ngwesə and so on: the point of writing this as [ŋŋwesə] 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 (28) illustrate the point that nouns in class 7 in the singular (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 rule of the language which we already know.

(28) **Singular (cl 7) | Plural (cl 8) | Plural locative**
ki-báo | i-báo | mwii-báo  ‘stool’
ki-bigá | i-bigá | mwii-bigá  ‘pot’
ki-bílíítu | i-bílíítu | mwii-bílíítu  ‘box of matches’
ki-bógojó | i-bógojó | mwii-bógojó  ‘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-/?

(29) **Singular (cl 7) | Plural (cl 8) | Plural locative**
kjáaí | jáaí | mujáaí~ɲɲáaí  ‘soup pot’
kjaáka | jaáka | mujaáka~ɲɲaáka  ‘bush’
kjnákí | jnákí | mujnákí~ɲɲnkí  ‘stump’
kjuúbá | juúbá | mujuúbá~ɲɲuúbá  ‘chest’

The data in (29) demonstrate a specific conclusion about the ordering of two of the rules motivated here: what is that conclusion?

### 5.2 Different effects of rule ordering

Besides showing how greater generality can often be achieved by splitting a process into smaller pieces, the preceding examples have illustrated that the application of one rule can bring 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 have this characteristic – sometimes applying one rule prevents a second rule from applying – and in this section we consider some of the effects of different rule orderings.

#### 5.2.1 Lamba: harmony and palatalization

The following data illustrate the interaction between a rule of vowel harmony and a palatalization rule in the language Lamba (Zambia):

(30) **Plain | Passive | Neuter | Applied | Reciprocal**
títa | títwa | títika | títila | tíitana  ‘do’
tula | tulwa | tulika | tulila | tulana  ‘dig’
In order to see what these data show, we must first understand the morphological structure of these words, a step which leads us to realize 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 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 suffixes /il/ and /iki/) to mid vowels when they are preceded by mid vowels.

(31) Height harmony

\[
\begin{pmatrix}
+\text{syl} \\
-\text{high}
\end{pmatrix} \rightarrow
\begin{pmatrix}
+\text{syl}
\\
-\text{high}
\\
-\text{low}
\end{pmatrix}
\]

There is an alternation in the realization of certain root-final consonants. As shown in examples such as kaka ~ katika and lasa ~ lajika, the velar consonants and the alveolar continuant s become alveopalatals when they are followed by the vowel i, by processes of palatalization. It is difficult to express a change of /lk/ and /s/ to alveopalatal by one rule without including /tl/ – which does not change, see [patika] – so two separate rules are needed.

(32) a. Stop Palatalization

\[
\begin{pmatrix}
+\text{high} \\
-\text{syl}
\end{pmatrix} \rightarrow
\begin{pmatrix}
+\text{cor}
\\
+\text{syl}
\\
+\text{high}
\\
-\text{back}
\end{pmatrix}
\]
b. **Fricative Palatalization**

\[
\begin{array}{c}
+\text{cont} \\
+\text{cor} \\
\rightarrow \text{[-ant]} \quad /_+\text{syl} \\
\quad +\text{high} \\
\quad -\text{back}
\end{array}
\]

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 required 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.

(33) /sek-ik-a/ underlying

seti'ika palatalization

*set'eka* 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.

(34) /sek-ik-a/ underlying

sekeka height harmony

(not applicable) palatalization

### 5.2.2 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/*.

(35) a. */at/*

| at-eiti | ‘to arrive’ |
| at-imti | ‘to take away’ |
| at-nejti | ‘to bring’ |
| at-leisti | ‘to forgive’ |
| at-likti | ‘to complete’ |
| at-ko:pti | ‘to rise’ |
| at-praž:ti | ‘to ask’ |
| at-kurti | ‘to reestablish’ |

| */ap/*
| ap-eiti | ‘to circumvent’ |
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.

(36) **Voicing assimilation**

\[
[-\text{son}] \rightarrow [+\text{voice}] / \_
\]

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-nefi/ → [atnefi], and /ab-mo:ki:ti/ → [apmo:ki:ti]. But there is clearly no rule prohibiting 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/.

(37) \begin{align*}
\text{ati-duoti} & \quad \text{‘to give back’} \\
\text{ati-dari:ti} & \quad \text{‘to open’} \\
\text{ati-det} & \quad \text{‘to delay’} \\
\text{ati-teisti} & \quad \text{‘to adjudicate’} \\
\text{api-berti} & \quad \text{‘to strew all over’} \\
\text{api-begti} & \quad \text{‘to run around’} \\
\text{api-puti} & \quad \text{‘to grow rotten’}
\end{align*}
Given just the voicing assimilation rule, you would expect forms such as *[adduoti], *[abberti] by analogy to [adbekti] and [abdauʒiti]. Lithuanian does not allow sequences of identical consonants, so to prevent such a result, an epenthetic vowel is inserted between homorganic obstruent stops (ones having the same values for the place of articulation features).

(38) Epenthesis

\[ \emptyset \rightarrow \begin{bmatrix} +\text{syl} \\ +\text{high} \\ -\text{back} \end{bmatrix} / \begin{bmatrix} -\text{cont} \\ -\text{son} \\ \alpha\text{ant} \\ \beta\text{cor} \end{bmatrix} \]

The ordering of these rules is important: epenthesis (38) 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 (Iran) dialect of Armenian, but they apply in the opposite order. If rules apply in a particular order, you would expect to find languages with essentially the same rules A and B where A precedes B in one language and B precedes A in another: this is what we find in comparing Armenian and Lithuanian.

The first-singular future prefix is underlyingly k-, as shown in (39a), 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 (39b) show, the prefix consonant first assimilates to the initial consonant of the root, and then is separated from that consonant by schwa.

(39) a. k-ertʰam
    k-asiem
    k-aniem
    k-akaniem
    k-oxniem
    k-uriem
    ‘I will go’
    ‘I will say’
    ‘I will do’
    ‘I will watch’
    ‘I will bless’
    ‘I will swell’

b. ka-tam
    ka-kienam
    gɔ-bozzam
    gɔ-λam
    ‘I will give’
    ‘I will exist’
    ‘I will buzz’
    ‘I will cry’
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.

5.2.3 Mongo: 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 (40), (41), and (46) with examples from Mongo (Congo). The first four examples demonstrate the shape of the various subject prefixes when they stand before a consonant.

The underlying forms of the subject prefixes are /N/ (which stands for a nasal consonant, whose exact place of articulation cannot be determined), /ol/, /al/, /tol/, /ol/, and /bal/. There is a vowel harmony process assimilating the closed vowel /ol/ to the open vowel /a/ when the following syllable contains either of the open vowels /ε/ or /ɔ/, and the prefix for first-singular subject assimilates in place of articulation to the following consonant.

The examples in (41) show how the subject prefixes are realized if the verb root begins with a vowel.

When the first-singular subject prefix stands before the root, it has the shape [nd3], which we will treat as being the result of insertion of [d3] between the prefix and a vowel-initial root. (We might also assume the
prefix /ndʒ/, which simplifies before a consonant, since such three-consonant sequences, viz. /ndʒ-sangal/, do not exist in the language.)

(42) **Consonant epenthesis**

\[
\emptyset \rightarrow \begin{cases} 
-\text{syl} \\
-\text{cons} \\
-\text{back}
\end{cases} /+[nas]+\_\text{V}
\]

The vowel /a/ deletes before another vowel, as shown by the third-singular and third-plural forms /a-ena/ → [ena] and /ba-ena/ → [bena].

(43) **Vowel truncation**

\[
[+\text{low}] \rightarrow \emptyset /\_\text{V}
\]

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

(44) **Glide formation**

\[
[+\text{round}] \rightarrow [−\text{syl}] /\_\text{V}
\]

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

(45) **Affrication**

\[
[+\text{cor}] \rightarrow [+\text{del.rel}] /\_\text{V} \left[ [−\text{syl}] \right] [+\text{high}]
\]

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 illustrates verb roots which underlyingly begin with the consonant /b/. As these data show, when underlying /b/ is preceded by a vowel, it is deleted.

(46) **Imp** 1sg 2sg 3sg 1pl 2pl 3pl

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.

(47) **Labial elision**

\[
\begin{cases} 
[+\text{voice}] \\
[+\text{ant}] \\
[−\text{cor}]
\end{cases} \rightarrow \emptyset /\_\text{V}_\_\text{V}
\]

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 intervocally. The ordering where b-deletion precedes vowel truncation and glide formation, illustrated in (48b), 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.)

(48) 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]

Mongo thus provides an example of the failure of rules – especially vowel truncation and glide formation – to apply to the output of a specific rule – b-deletion – which we explain by ordering b-deletion after the vowel rules.

5.2.4 Examples for discussion

Karok. These data from Karok (California) 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.

(49) Imperative 1sg  3sg
    pasip  nipasip  ?upasip  ‘shoot’
    kifnuk  nikifnuk  ?ukifnuk  ‘stoop’
    suprih  ni:juprih  ?usuprih  ‘measure’
    ?ifik  ni:jifik  ?u?ifik  ‘pick up’
    ?aktuv  ni:jaktuv  ?u?aktuv  ‘pluck at’
    ?akrap  ni:jakrap  ?u?akrap  ‘slap’
    ?arip  ni:jarip  ?u?arip  ‘cut a strip’
    ?axjar  nixjar  ?uxjar  ‘fill’
    ?i:jkak  nijkak  ?uskak  ‘jump’
Shona. Often, a seemingly complex problem can be significantly simplified by breaking the problem up into a few interacting processes. If you look at the phonetic realizations of the passive suffix in Shona (Zimbabwe), you 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.

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 -tʃa-, -no-, and -a-, or no marker, finally followed by the verb stem.

(51) Subjective	Future
urime ‘that you (sg) plow’
mutərima ‘you (pl) will plow’
turime ‘that they (pl) plow’
tutərima ‘they (pl) will plow’
kunətə ‘that there be nice’
kutənanə ‘there will be nice’

Habitual	Recent past
unorima ‘you (sg) plow’
munorima ‘you (pl) plow’
tunorima ‘they (pl) plow’
kunonatsa ‘there is nice’
warima ‘you (sg) plowed’
mwarima ‘you (pl) plowed’
txwarima ‘they (pl) plowed’
kwanatsa ‘there was nice’

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

Klamath. The data in (52)-(56) from Klamath (Oregon) 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 (52) 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 j, which is not crucial).

(52) la:p-a ‘two (obj.)’
la:p ‘two’
la:p-pli ‘puts on a blanket’
q’la:tʃ-aksi ‘Blueberry Place’
q’la:tʃ ‘blueberry (sp)’
pq-a ‘bakes camas’
pq-s ‘camas root’
lai ‘is rich’
lai’-a:ka ‘little chief’

The data in (53) provide examples of underlyingly glottalized obstruents, which become plain voiceless consonants unless they are followed by a vowel or plain sonorant

(53) p’ak’-a ‘smashes’
p’ak-ska ‘chips off (intr)’
ked-’a ‘distributes’
se-ked-s ‘Saturday’
pq-pq’-a ‘becomes dusty’
pq-tki ‘becomes dusty’
tʃh-a:k’-a ‘melts (intr)’
tʃh-a:k-tki ‘melts (as butter)’
h-ʃh-itʃ-’a ‘makes shavings’
k-ʃh-itʃ-ta ‘scraps one’s foot on’
tʃh-lo:q’-a ‘is smooth’
tʃh-lo:q-tki ‘becomes slick’
Data in (53) show that aspirated consonants deaspirate in this same context.

(54) lit\textsuperscript{h}lit\textsuperscript{f}l-i ‘strong’ li:t\textsuperscript{f}tki ‘becomes strong’
ponw-\textsuperscript{h}t\textsuperscript{h}a ‘while drinking’ ponw-o:t\textsuperscript{h}s ‘something to drink with’
so\textsuperscript{h}a ‘kindles a fire’ so:t\textsuperscript{f}ti:la ‘lights a fire under’
sij\textsuperscript{h}t\textsuperscript{h}a ‘trades (pl obj) with each other’ sij\textsuperscript{t}t-pli ‘trade back (pl obj)’
n’iq\textsuperscript{h}o:wa ‘keeps putting a hand in water’ n’iq-tpa ‘reaches and touches’

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

(55) laq\textsuperscript{t}a ‘suspects s.o.’ sa-lq\textsuperscript{t}a ‘suspects e.o.’
mat\textsuperscript{h}\textsuperscript{a}\textsuperscript{t}-ka ‘listens’ sna-m\textsuperscript{t}a\textsuperscript{t}-i:la ‘causes to hear’
met\textsuperscript{a} ‘moves camp’ me-m\textsuperscript{t}a ‘moves (distributive)’

saq\textsuperscript{t}ka ‘ask for s.t.’ sa-sq\textsuperscript{t}qa ‘ask for s.t. (distributive)’
sit\textsuperscript{d}\textsuperscript{h}aq\textsuperscript{h}wa ‘wash hands’ hi-st\textsuperscript{d}\textsuperscript{h}aq-t\textsuperscript{h}a ‘are angry with e.o’
som ‘mouth’ so-sm\textsuperscript{d}a:k ‘little mouths (distributive)’

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

(56) q’ot\textsuperscript{f}a ‘bends’ jo-q\textsuperscript{f}a ‘bends with the feet’
q\textsuperscript{h}ew\textsuperscript{a} ‘breaks’ t\textsuperscript{h}e-g\textsuperscript{u}a ‘sit on and break’
t\textsuperscript{h}ew\textsuperscript{a} ‘surface cracks’ je-t\textsuperscript{w}a ‘steps on and cracks surface’

s-t\textsuperscript{f}iq\textsuperscript{a} ‘squash with a pointed instrument’ ji-t\textsuperscript{q}a ‘squash by pressure with the feet’
w-k’al\textsuperscript{a} ‘cuts with a long instrument’ kin-k\textsuperscript{l}a ‘makes a mark with pointer’
w-p’eq\textsuperscript{a} ‘hits in the face with a long instrument’ hom-pq\textsuperscript{a} ‘flies in the face’
Exercises

1 Kerewe

What two tone rules are motivated by the following data? Explain what order the rules apply in. Vowels have no accent with L tone: treat H tones as [+H] and L tones as [−H].

<table>
<thead>
<tr>
<th></th>
<th>to V</th>
<th>to V e.o.</th>
<th>to V for</th>
<th>to V for e.o.</th>
</tr>
</thead>
<tbody>
<tr>
<td>kubala</td>
<td>kubalana</td>
<td>kubalila</td>
<td>kubalilana</td>
<td>‘count’</td>
</tr>
<tr>
<td>kugaja</td>
<td>kugajana</td>
<td>kugajila</td>
<td>kugajilana</td>
<td>‘despise’</td>
</tr>
<tr>
<td>kugula</td>
<td>kugulana</td>
<td>kugulila</td>
<td>kugulilana</td>
<td>‘buy’</td>
</tr>
<tr>
<td>kubála</td>
<td>kubálána</td>
<td>kubálila</td>
<td>kubálilana</td>
<td>‘kick’</td>
</tr>
<tr>
<td>kulúma</td>
<td>kulúmána</td>
<td>kulúmila</td>
<td>kulúmilana</td>
<td>‘bite’</td>
</tr>
<tr>
<td>kusúna</td>
<td>kusúnána</td>
<td>kusúnila</td>
<td>kusúnilana</td>
<td>‘pinch’</td>
</tr>
<tr>
<td>kulába</td>
<td>kulálána</td>
<td>kulálila</td>
<td>kulálilana</td>
<td>‘pass’</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>to V us</th>
<th>to V it</th>
<th>to V for us</th>
<th>to V it for us</th>
</tr>
</thead>
<tbody>
<tr>
<td>kutubála</td>
<td>kutubálá</td>
<td>kutubálila</td>
<td>kutubálilila</td>
<td>‘count’</td>
</tr>
<tr>
<td>kutúgája</td>
<td>kutúgája</td>
<td>kutúgájila</td>
<td>kutúgajilila</td>
<td>‘despise’</td>
</tr>
<tr>
<td>kutúgúla</td>
<td>kutúgúla</td>
<td>kutúgúila</td>
<td>kutúgúilila</td>
<td>‘buy’</td>
</tr>
<tr>
<td>kutúbála</td>
<td>kutúbálá</td>
<td>kutúbálila</td>
<td>kutúbáilila</td>
<td>‘kick’</td>
</tr>
<tr>
<td>kutúlúma</td>
<td>kutúlúma</td>
<td>kutúlúnila</td>
<td>kutúlúnila</td>
<td>‘bite’</td>
</tr>
<tr>
<td>kutúsúna</td>
<td>kutúsúna</td>
<td>kutúsúnila</td>
<td>kutúsúnila</td>
<td>‘pinch’</td>
</tr>
<tr>
<td>kutúlaba</td>
<td>kutúlaba</td>
<td>kutúlábila</td>
<td>kutúlábila</td>
<td>‘pass’</td>
</tr>
</tbody>
</table>

2 Mbunga

Account for the phonological alternations in the following data. Note that there are two roots for ‘beat,’ ‘cut,’ ‘rub,’ also there are derivational relations indicated with suffixes (-el-, -il-, -is-, -es-, etc.) which you need not account for: except for the difference between final -a and final -i which mark different tenses, you do not need to be concerned with possible suffixes and alternations caused by suffixes.
What phonological rules are motivated by the following examples, and what order do those rules apply in?

3 Polish

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

<table>
<thead>
<tr>
<th>Singular</th>
<th>Plural</th>
<th>Singular</th>
<th>Plural</th>
</tr>
</thead>
<tbody>
<tr>
<td>klup</td>
<td>klubi</td>
<td>trup</td>
<td>trupi</td>
</tr>
<tr>
<td>dom</td>
<td>domi</td>
<td>snop</td>
<td>snopi</td>
</tr>
<tr>
<td>ʒwup</td>
<td>ʒwobi</td>
<td>trut</td>
<td>trudi</td>
</tr>
<tr>
<td>dzvon</td>
<td>dzvoni</td>
<td>kot</td>
<td>koti</td>
</tr>
<tr>
<td>lut</td>
<td>lodi</td>
<td>grus</td>
<td>gruzi</td>
</tr>
<tr>
<td>nos</td>
<td>nosi</td>
<td>vus</td>
<td>vozi</td>
</tr>
<tr>
<td>wuk</td>
<td>wugi</td>
<td>wuk</td>
<td>wuki</td>
</tr>
<tr>
<td>sok</td>
<td>soki</td>
<td>ruk</td>
<td>rogi</td>
</tr>
<tr>
<td>bur</td>
<td>bori</td>
<td>vuu</td>
<td>vowi</td>
</tr>
<tr>
<td>sul</td>
<td>soli</td>
<td>buj</td>
<td>boji</td>
</tr>
<tr>
<td>ʃum</td>
<td>ʃumi</td>
<td>ʒur</td>
<td>ʒuri</td>
</tr>
</tbody>
</table>
## 4 Logoori

Account for the vowel alternations in the following data. Tone may be ignored.

<table>
<thead>
<tr>
<th>‘they just V’d’</th>
<th>‘they just V’d for’</th>
<th>‘they will V’ (rem. fut)</th>
<th>‘they will V for’ (rem. fut)</th>
</tr>
</thead>
<tbody>
<tr>
<td>váakátáanga</td>
<td>váakátáängra</td>
<td>varakátáanga</td>
<td>varakátáängra</td>
</tr>
<tr>
<td>váakávinjaanja</td>
<td>váakávinjaanja</td>
<td>varakávinjaanja</td>
<td>varakávinjaanja</td>
</tr>
<tr>
<td>váakázáázama</td>
<td>váakázáázama</td>
<td>varakázáázama</td>
<td>varakázáázama</td>
</tr>
<tr>
<td>váakávuruganja</td>
<td>váakávuruganja</td>
<td>varakávuruganja</td>
<td>varakávuruganja</td>
</tr>
<tr>
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<td>váakakanagananja</td>
<td>varakakanagananja</td>
<td>varakakanagananja</td>
</tr>
<tr>
<td>váakar</td>
<td>váakar</td>
<td>varakar</td>
<td>varakar</td>
</tr>
<tr>
<td>váakást</td>
<td>váakást</td>
<td>varakást</td>
<td>varakást</td>
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</table>

The following nouns illustrate a productive pattern for making nouns ‘tool for V-ing with’:

- ividijiru ‘pound’
- ivivéginga ‘shave’
- ivikárárugr | ‘cut’
- ivisómmera ‘read’
- ivíniru ‘dance’
- ivínágíllu ‘catch’
- ivisémhello ‘cultivate’
- ivírunjgiru ‘season’
5 Shona

Acute accent indicates H tone and unaccented vowels have L tone. Given the two sets of data immediately below, what tone rule do the following data motivate? There are alternations in the form of adjectives, e.g. kurefu´, karefu´, marefu´ all meaning 'long.' Adjectives have an agreement prefix, hence ku-refu´ 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. gürú ~ kürú ~ hürú, which need not be explained.

bveni 'baboon' bveni pfúpi 'short baboon'
táfura 'table' táfura húrú 'big table'
joko 'word' joko bvúpi 'short word'
şadzá 'hoe' šadzá gúrú 'big hoe'
zigómaná 'boy' zigómaná gúrú 'big boy'

(augmentative)

imbá 'house' imbá t'éna 'clean house'
mará 'gazelle' mará t'éna 'clean gazelle'
marí 'money' marí t'éna 'clean money'
şängá 'knife' şängá gúrú 'big knife'
đémí 'axe' đémo bvúpi 'short axe'
ňúmê 'messenger' ńúme pfúpi 'short messenger'
d'irá 'cloth' d'ira d'éna 'clean cloth'
ći 'pot' hì húrú 'big pot'

mbündúdzi 'worms' mbündúdzi húrú 'big worms'
fúma 'wealth' fúma t'éna 'clean wealth'
ńíka 'country' ńika húrú 'big country'
ńáká 'bones' ńáká pfúpi 'short bones'
dékéra 'pumpkin' dékéra gúrú 'big pumpkin'

These data provide further illustration of the operation of this tone rule, which will help you to state the conditions on the rule correctly.

guó 'baboon' guó rákafá 'the baboon died'
şaqú 'hoe' šaqú rákawá 'the hoe fell'
núgú 'porcupine' núgú jákafá 'the porcupine died'

şängá 'knife' şängá rákawá 'the knife fell'
ńúmê 'messenger' ńúme jákafá 'the messenger died'
búku 'book' búku rákawá 'the book fell'

mapfeni 'baboons' mapfeni makú rú 'big baboons'
mapadzá 'hoes' mapadzá makú rú 'big hoes'
mapángá 'knives' mapángá makú rú 'big knives'
ńúmê 'messenger' ńúme ndáfú 'tall messenger'
matémó 'axes' matémó mapfúpi 'short axes'

In the examples below, a second tone rule applies.
What do the following examples show about these tone rules?

<table>
<thead>
<tr>
<th>Guò</th>
<th>‘baboon’</th>
<th>Guò refú</th>
<th>‘tall baboon’</th>
</tr>
</thead>
<tbody>
<tr>
<td>Búku</td>
<td>‘book’</td>
<td>Búku refú</td>
<td>‘long book’</td>
</tr>
<tr>
<td>Ńadžá ‘hoe’</td>
<td>Ndu</td>
<td>Ndu refú</td>
<td>‘long hoe’</td>
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<tr>
<td>Nuŋgu ‘porcupine’</td>
<td>Nuŋgu ndefú</td>
<td>‘long porcupine’</td>
<td></td>
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<tr>
<td>Mafóko ‘words’</td>
<td>Mafóko marefu</td>
<td>‘long words’</td>
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<tr>
<td>Kuṣika ‘to the land’</td>
<td>Kuṣika kurefu</td>
<td>‘to the long land’</td>
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<tr>
<td>Mapadžá ‘hoses’</td>
<td>Mapadžá marefu</td>
<td>‘long hoes’</td>
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<tr>
<td>Kamará ‘gazelle (dim)’</td>
<td>Kamará karefu</td>
<td>‘long gazelle (dim)’</td>
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<tr>
<td>Tunugü ‘porcupines (dim)’</td>
<td>Tunugü turefu</td>
<td>‘long porcupines (dim)’</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Guò</th>
<th>‘baboon’</th>
<th>Guò gobvu</th>
<th>‘thick baboon’</th>
</tr>
</thead>
<tbody>
<tr>
<td>Búku</td>
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<td>Búku gobvu</td>
<td>‘thick book’</td>
</tr>
<tr>
<td>Ńadžá ‘hoe’</td>
<td>Ndu</td>
<td>Ndu gobvu</td>
<td>‘thick hoe’</td>
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<tr>
<td>Makuñu ‘baboons’</td>
<td>Makuñu makobvu</td>
<td>‘thick baboons’</td>
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<tr>
<td>Mapadžá ‘hoses’</td>
<td>Mapadžá makobvu</td>
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<tr>
<td>Tsamba ‘letter’</td>
<td>Tsamba nefe</td>
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<td>Búku</td>
<td>‘book’</td>
<td>Búku dëte</td>
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<td>Ńadžá ‘hoe’</td>
<td>Ndu</td>
<td>Ndu dëte</td>
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<tr>
<td>Imba ‘house’</td>
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<td>‘thick house’</td>
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6 Guérze

Account for the phonological alternations in the following data from Guérze. Be sure that you state the order of the rules which you propose, and justify your conclusion about ordering.

<table>
<thead>
<tr>
<th>Bamaŋ</th>
<th>‘harp-drum’</th>
<th>Bama bo</th>
<th>‘10 harp-drums’</th>
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</thead>
<tbody>
<tr>
<td>Bama dɔnɔ</td>
<td>‘1 harp-drum’</td>
<td>Bama naalu</td>
<td>‘5 harp-drums’</td>
</tr>
<tr>
<td>Bama tɔdono</td>
<td>‘100 harp-drums’</td>
<td>Bama ɲuja</td>
<td>‘heavy harp-drum’</td>
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<tr>
<td>Balá</td>
<td>‘yam’</td>
<td>Balá kujaa</td>
<td>‘long yam’</td>
</tr>
<tr>
<td>Balá bsalu</td>
<td>‘5 yams’</td>
<td>Balá nee</td>
<td>‘bad yam’</td>
</tr>
<tr>
<td>Balá tɔyα</td>
<td>‘black yam’</td>
<td>Balá jyo</td>
<td>‘wet yam’</td>
</tr>
<tr>
<td>Gbɔŋ</td>
<td>‘wood’</td>
<td>Gbɔ naa</td>
<td>‘4 wood pieces’</td>
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<tr>
<td>Gbɔ jyo</td>
<td>‘wet wood’</td>
<td>Gbɔ nɛna</td>
<td>‘new wood’</td>
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<td>Hiiŋ</td>
<td>‘design’</td>
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</tr>
<tr>
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<td>‘long design’</td>
<td>Hii ga</td>
<td>‘big design’</td>
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<tr>
<td>Hii naa</td>
<td>‘4 designs’</td>
<td>Hii ɲo</td>
<td>‘bad design’</td>
</tr>
<tr>
<td>Hii nokolo</td>
<td>‘small design’</td>
<td>Hii</td>
<td>‘thing’</td>
</tr>
<tr>
<td>Ha ɲeŋ</td>
<td>‘black thing’</td>
<td>Ha ga</td>
<td>‘big thing’</td>
</tr>
<tr>
<td>Ha jyo</td>
<td>‘wet thing’</td>
<td>Ha ɲudono</td>
<td>‘100 things’</td>
</tr>
<tr>
<td>Ha ɲuja</td>
<td>‘heavy thing’</td>
<td>Hii</td>
<td>‘suitcase’</td>
</tr>
<tr>
<td>Kihi ɲuja</td>
<td>‘long suitcase’</td>
<td>Kihi lokolo</td>
<td>‘small suitcase’</td>
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</tbody>
</table>
7 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 \([\beta, \delta, \gamma]\), in terms of predictability.

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*INTRODUCTION PHONOLOGY*
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. Pay attention to what consonants actually exist in the language.

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<td>aurinot</td>
<td>aurinolta</td>
<td>aurinkona</td>
</tr>
<tr>
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<td>rečjit</td>
<td>rečjiltæ</td>
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</tr>
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<td>vačjit</td>
<td>vačjiltæ</td>
<td>vačkina</td>
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<td>kellona</td>
</tr>
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<td>kellat</td>
<td>kellalta</td>
<td>keliana</td>
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<td>silta</td>
<td>sillat</td>
<td>sillalta</td>
<td>siltana</td>
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<td>kullat</td>
<td>kullalta</td>
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<td>virta</td>
<td>virrat</td>
<td>virralla</td>
<td>virtana</td>
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<td>parran</td>
<td>parta</td>
<td>parrat</td>
<td>parralta</td>
<td>partana</td>
</tr>
</tbody>
</table>

**Further reading**

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, you will 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 recognize 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.

### 6.1 Yawelmani

Our first problem involves alternations in the verb paradigm in the Yawelmani dialect of Yokuts (California).

#### 6.1.1 The data

Three phonological rules will be motivated by the following examples: vowel epenthesis, vowel shortening, and vowel harmony. It is not obvious what the underlying representation of verb roots is, so besides finding the rules we must make decisions about underlying forms.

<table>
<thead>
<tr>
<th>(1)</th>
<th>Nonfuture</th>
<th>Imperative</th>
<th>Dubitative</th>
<th>Passive aorist</th>
</tr>
</thead>
<tbody>
<tr>
<td>xathin</td>
<td>xatk’a</td>
<td>xatal</td>
<td>xatit</td>
<td>‘eat’</td>
</tr>
<tr>
<td>dubhun</td>
<td>dubk’a</td>
<td>dubal</td>
<td>dubut</td>
<td>‘lead by hand’</td>
</tr>
<tr>
<td>xilhin</td>
<td>xilk’a</td>
<td>xilal</td>
<td>xilit</td>
<td>‘tangle’</td>
</tr>
<tr>
<td>k’o?hin</td>
<td>k’o?k’o</td>
<td>k’o?ol</td>
<td>k’o?it</td>
<td>‘throw’</td>
</tr>
<tr>
<td>doshin</td>
<td>dosk’o</td>
<td>do:sol</td>
<td>do:sit</td>
<td>‘report’</td>
</tr>
<tr>
<td>šaphin</td>
<td>šap’ka</td>
<td>ša:pal</td>
<td>ša:pit</td>
<td>‘burn’</td>
</tr>
<tr>
<td>lanhin</td>
<td>lan’ka</td>
<td>la:nal</td>
<td>la:nit</td>
<td>‘hear’</td>
</tr>
<tr>
<td>mek’hin</td>
<td>mek’k’a</td>
<td>me:k’al</td>
<td>me:k’it</td>
<td>‘swallow’</td>
</tr>
<tr>
<td>wonhin</td>
<td>won’ko</td>
<td>wo:nol</td>
<td>wo:nit</td>
<td>‘hide’</td>
</tr>
<tr>
<td>p’a:xathin</td>
<td>p’a:xtk’a</td>
<td>p’axa:tal</td>
<td>p’axa:tit</td>
<td>‘mourn’</td>
</tr>
<tr>
<td>hiwethin</td>
<td>hiwetk’a</td>
<td>hiwe:tal</td>
<td>hiwe:tit</td>
<td>‘walk’</td>
</tr>
<tr>
<td>jawalhin</td>
<td>jawalk’a</td>
<td>jawa:lal</td>
<td>jawa:lit</td>
<td>‘follow’</td>
</tr>
<tr>
<td>logiwhin</td>
<td>logiwk’a</td>
<td>logwl</td>
<td>logwit</td>
<td>‘pulverize’</td>
</tr>
<tr>
<td>lihimhin</td>
<td>lihimk’a</td>
<td>lihmal</td>
<td>lihmit</td>
<td>‘run’</td>
</tr>
</tbody>
</table>
t’ojixhin     t’ojixk’a     t’ojxol     t’ojxit       ’give medicine’
lu:k’ulhun     lu:k’ulk’a     lu:k’al     lu:k’lut       ’bury’
so:milhin     so:milk’a     sonlol     sonlit       ’put on back’
ʔa:milhin     ʔa:milk’a     ʔamlol     ʔamlit       ’help’
mo:jinhin     mo:jink’a     mojnol     mojnit       ’become tired’
sha:lik’hin    sha:lik’k’a    šalk’al    šalk’it       ’wake up’

6.1.2 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 due to 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 in the face of new evidence – 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 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 versus 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’       šap ~ ša: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’
jawal ~ jawa:l    ‘follow’       paʔit ~ paʔit’       ‘fight’
ʔilik ~ ʔilik      ‘sing’       logiw ~ logw       ‘pulverize’
ʔugun ~ ʔugn       ‘drink’       lihim ~ lihm       ‘run’
ʔajj ~ ʔajj       ‘pole a boat’       t’ojix ~ t’ojx       ‘give medicine’
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)  
-\(\text{hin}\) xat, xil, k’o?, dos, šap, lan, mek’, won, p’axat, hiwet, ?opo\(t\), jawal, pa?i\(j\), ?ilik, logiw, lihim, ?ajij, t’o\(j\)ix, so:nil, ?a:mil, mojin, ša:lik’
-\(\text{hun}\) dub, ?ugun, luk’ul
-\(\text{k’a}\) xat, dub, xil, šap, lan, mek’, p’axat, hiwet, jawal, pa?i\(j\), ?ilik, logiw, ?ugun, lihim, ?ajij, t’o\(j\)ix, luk’ul, so:nil, ?a:mil, mojin, ša:lik’
-\(\text{k’o}\) k’o?, dos, won, ?opo\(t\)
-\(\text{ol}\) k’o?, dos, won, ?opo\(t\), logw, t’o\(j\)x, sonl, mojn
-\(\text{it}\) xat, xil, k’o?, dos, šap, la:n, me:k’, won, p’axat, hiwet, ?opo\(t\), jawal, pa?i\(j\), ?ilik, logiw, lihim, ?ajij, t’o\(j\)x, sonl, ?a:mil, moijn, ša:lik’
-\(\text{ut}\) dub, ?ugun, luk’ul

6.1.3 Identifying phonological regularities

**Vowel harmony.** Having grouped the examples in this fashion, a phonological regularity can be detected. For the suffix \(\text{hin} \sim \text{hun}\), the vowel \(\text{u}\) appears when the preceding vowel is \(\text{u}\), and \(\text{i}\) appears in the suffix after any other vowel. The suffix \(\text{it} \sim \text{ut}\) obeys this same rule. The suffixes \(\text{k’a} \sim \text{k’o}\) and \(\text{al} \sim \text{ol}\) have the vowel \(\text{o}\) after \(\text{o}\). This can be explained by positing a rule of vowel harmony between the suffix vowel and whatever vowel precedes it, where \(\text{lal}\) assimilates to \(\text{lo}\) and \(\text{li}\) assimilates to \(\text{lu}\).

(4) \[
\begin{bmatrix}
V \\
\alpha_{\text{high}}
\end{bmatrix} \rightarrow \left[ + \text{round} \right] / \begin{bmatrix}
V \\
\alpha_{\text{high}}
\end{bmatrix} \quad C_{\text{o}}^+ \]

The variable notation – \(\alpha_{\text{high}}\)… \(\alpha_{\text{high}}\) – expresses the condition that the vowels must have the same value of [high], i.e. the harmonizing vowel must be [+high] after a [+high] round vowel, and [−high] after a [−high] 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’o?
   CVC ~ CV:C - dos ~ do:s, sap ~ ša:p, lan ~ la:n, mek’ ~ me:k’,
                  won ~ wɔ:n
   CVCVC ~ CVCC:C - p’axat ~ p’axat, hiwet ~ hiwet, ṭopot ~ ṭopot,
                     jawal ~ jawa:l
   CVCVC ~ CVCC - paʔit ~ paʔi, ṭilik ~ ṭilik, logiw ~ logw, ṭugun
                  ~ ṭugun, lihim ~ lihm, ṭajj ~ ṭajj, t’ojix ~ t’ojx,
                   luk’ul ~ luk’l
   CV:VC ~ CVCC - so:nil ~ sonl, ṭa:mil ~ ṭa:mil, mojin ~ mojn,
                  ša:lik’ ~ šalk’

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 would make it hard to account for stems such as /xat/ which are invariant CVC. We could not predict whether a stem vowel is supposed to have a length alternation or not, and the reasoning that leads to hypothesizing an 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) the word for ‘time’ is underlyingly /raz/ and for ‘forest’ it is /les/.

Given the conclusion that stems like /do:s/ ~ /do:s/ 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.

\[(7) \ V \rightarrow [\text{-long}] \ \_ \ CC\]

This rule is all that is needed to explain both the invariant CVC stems and the alternating CV:C \~\ CVC stems. Underlyingly /dос-hin/ undergoes (7) and gives the surface form [doshin] – all other forms preserve the underlying length of the vowel. 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 alternations 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: consideration of alternative hypotheses is an essential part of problem solving.

First suppose that the vowel is not part of the underlying representation of the stem. In that case, we assume the following representations

\[(8) \ \begin{array}{lllll}
\text{underlying} & ?\text{iIk-hin} & ?\text{iIk-k’a} & ?\text{iIk-al} & ?\text{iIk-it} \\
\text{surface} & ?\text{iIk-hin} & ?\text{iIk-k’a} & ?\text{iIk-al} & ?\text{iIk-it} \\
\text{underlying} & ?\text{aIk’-hin} & ?\text{aIk’-k’a} & ?\text{aIk’-al} & ?\text{aIk’-it} \\
\text{surface} & ?\text{aIk’-hin} & ?\text{aIk’-k’a} & ?\text{alk’-al} & ?\text{alk’-it} \\
\end{array}\]
Focusing on the hypothesized underlying representations where a vowel might be inserted, we notice that a vowel appears only where 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 unpredictable information must be in the underlying form. The vowel in the second syllable is always high, and is round when 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. Given the harmony rule, we can assume that the second vowel is i. It is then possible to account for these examples by applying the following rule of epenthesis.

(9) \( \emptyset \rightarrow V / C \_ \_ \_ C \) \\
\[ +\text{high} \]

Given (9), 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 stems like /ʔilik/, epenthesis applies to underlying /CV:CC+CV(C)/ to give surface [CV:CiC+CV(C)]: /ʔilik-hin/ → [ʔilikhin]. The alternant CVCC before VC suffixes ~ [ʔilik] ~ directly reflects the underlying form.

For /CV:CC/ stems like /ʂa:lk/’, epenthesis will also apply to underlying /CV:CC+CV(C)/, giving the surface form [CV:CiC+CV(C)]: /ʂa:lk-hin/ → [ʂa: likhin]. When a VC suffix is added to such stems, there is no epenthesis, but we do find shortening of the underlyingly long vowel which stands before a consonant cluster: (/ʂa:lkal/ → [ʂalkal]). The rules of vowel harmony, epenthesis, and vowel shortening, combined with our analyses of underlying representations, account for all aspects of the data in (1). We conclude that epenthesis is a possible account of these alternations.

The preceding analysis has assumed a rule of epenthesis based on underlying representations of the form /CVCC/ and /CV:CC/, but we should explore the competing hypothesis that the vowel found in these stems is not inserted, and 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, ʔajij, t’ojix, luk’ul so:nil, ʔa:mil, mo:jin, ʂa: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).
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 produce too general a rule, since there are many vowels in open syllables, viz. xatal, k’oʔit, doːsit, ḥaːtthin, and p’axaːtal among others. In some of these, 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’xaːtal, and we see no word-initial clusters of consonants. If we are to have vowel deletion, the rule must be restricted from creating such clusters, so 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)  \[ V \rightarrow ∅ / VC_CV \]

This rule still makes incorrect predictions, since in fact there are vowels in the context VC_CV, as shown by forms such as p’axaːtal, ḥoːp̂iti, 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)  \[ V \rightarrow ∅ / VC___CV \]

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.

### 6.1.4 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 choose 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.

We should also consider the factual predictions of the two analyses. The epenthesis analysis predicts that there should be no CCC sequences in the language, 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 if there are VCCVC 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 would not hold for the whole language, if the author of the grammar were not aware of all relevant types of examples.

### 6.2 Hehe

The following data illustrate phonological processes of Hehe (Tanzania). Each noun is in one of fifteen 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.
### 6.2.1 The data

Here are the relevant data from nouns.

(14) **Class 1**

<table>
<thead>
<tr>
<th>Noun</th>
<th>English</th>
</tr>
</thead>
<tbody>
<tr>
<td>mutesi</td>
<td>‘trapper’</td>
</tr>
<tr>
<td>mutelesi</td>
<td>‘cook’</td>
</tr>
<tr>
<td>mwiimbi</td>
<td>‘singer’</td>
</tr>
<tr>
<td>mwaasi</td>
<td>‘builder’</td>
</tr>
<tr>
<td>mooofusi</td>
<td>‘one who washes’</td>
</tr>
</tbody>
</table>

**Class 2**

<table>
<thead>
<tr>
<th>Noun</th>
<th>English</th>
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<tbody>
<tr>
<td>vatesi</td>
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</tr>
<tr>
<td>vatelesi</td>
<td>‘cooks’</td>
</tr>
<tr>
<td>viimbi</td>
<td>‘singers’</td>
</tr>
<tr>
<td>vaasi</td>
<td>‘builders’</td>
</tr>
<tr>
<td>woofusi</td>
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</tr>
</tbody>
</table>

**Class 3**

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<td>muhoomi</td>
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</tr>
<tr>
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<td>‘cover’</td>
</tr>
<tr>
<td>mwiina</td>
<td>‘hole’</td>
</tr>
<tr>
<td>mweenda</td>
<td>‘cloth’</td>
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<td>muu</td>
<td>‘salt’</td>
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</table>

**Class 4**

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</tr>
</thead>
<tbody>
<tr>
<td>mihoomi</td>
<td>‘cow humps’</td>
</tr>
<tr>
<td>mihogo</td>
<td>‘cassava’</td>
</tr>
<tr>
<td>miina</td>
<td>‘holes’</td>
</tr>
<tr>
<td>mjeenda</td>
<td>‘cloths’</td>
</tr>
<tr>
<td>muu</td>
<td>‘salts’</td>
</tr>
</tbody>
</table>

**Class 6**

<table>
<thead>
<tr>
<th>Noun</th>
<th>English</th>
</tr>
</thead>
<tbody>
<tr>
<td>mavafi</td>
<td>‘hairy caterpillars’</td>
</tr>
<tr>
<td>maboga</td>
<td>‘pumpkins’</td>
</tr>
<tr>
<td>miino</td>
<td>‘teeth’</td>
</tr>
<tr>
<td>mava</td>
<td>‘hairy caterpillars’</td>
</tr>
<tr>
<td>masaasi</td>
<td>‘bullets’</td>
</tr>
<tr>
<td>majaji</td>
<td>‘legs’</td>
</tr>
<tr>
<td>miiho</td>
<td>‘eyes’</td>
</tr>
</tbody>
</table>

**Class 7**

<table>
<thead>
<tr>
<th>Noun</th>
<th>English</th>
</tr>
</thead>
<tbody>
<tr>
<td>kigidi</td>
<td>‘waist’</td>
</tr>
<tr>
<td>kisogo</td>
<td>‘back of head’</td>
</tr>
<tr>
<td>tʃuunga</td>
<td>‘wet lowland’</td>
</tr>
<tr>
<td>kifuniko</td>
<td>‘tiny cover’</td>
</tr>
<tr>
<td>kihoomi</td>
<td>‘tiny cow hump’</td>
</tr>
<tr>
<td>tʃooto</td>
<td>‘tiny fire’</td>
</tr>
<tr>
<td>tʃuŋu</td>
<td>‘tiny salt’</td>
</tr>
<tr>
<td>kiina</td>
<td>‘tiny hole’</td>
</tr>
<tr>
<td>kingaamba</td>
<td>‘sweet potato’</td>
</tr>
</tbody>
</table>

**Class 8**

<table>
<thead>
<tr>
<th>Noun</th>
<th>English</th>
</tr>
</thead>
<tbody>
<tr>
<td>figidi</td>
<td>‘waists’</td>
</tr>
<tr>
<td>fisogo</td>
<td>‘backs of head’</td>
</tr>
<tr>
<td>fjuunga</td>
<td>‘wet lowlands’</td>
</tr>
<tr>
<td>fifuniko</td>
<td>‘tiny covers’</td>
</tr>
<tr>
<td>fifoomi</td>
<td>‘tiny cow humps’</td>
</tr>
<tr>
<td>fjooto</td>
<td>‘tiny fires’</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Noun</th>
<th>English</th>
</tr>
</thead>
<tbody>
<tr>
<td>fingoamba</td>
<td>‘sweet potatoes’</td>
</tr>
<tr>
<td>fjuula</td>
<td>‘frogs’</td>
</tr>
<tr>
<td>fjaanga</td>
<td>‘graves’</td>
</tr>
<tr>
<td>fivili</td>
<td>‘tiny bodies’</td>
</tr>
<tr>
<td>fivafi</td>
<td>‘tiny hairy caterpillars’</td>
</tr>
<tr>
<td>fjeenda</td>
<td>‘tiny cloths’</td>
</tr>
</tbody>
</table>
As always, a preliminary morphological analysis is the first step in solving this 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 mu-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, va-, and w- for class 2, mi-, mj-, and m- for class 4, ma- and m- for class 6, ki- and t- for class 7, fi- and fj- 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.

### 6.2.2 Morphological analysis

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### 6.2.3 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 are -tesi (cf. mu-tesi,
va-tesi) and -lagusi (cf. mu-lagusi, va-lagusi); examples of stems which begin
with vowels are -iimbi (cf. mw-iimbi, v-iimbi) and -endi (mw-endi, v-endi).
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 (what may 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 the words for ‘singer’ and ‘singers’ would be /muiimbi/ 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 versus 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 hypoth-
eses and test them against the data. We therefore assume the following
rules of glide formation and vowel deletion.

\[
\begin{align*}
(15) & \ V \rightarrow [-\text{syll}] / -V \\
& \quad [-\text{high}] \\
\text{glide formation} \\
(16) & \ V \rightarrow \emptyset / -V \\
\text{a-deletion}
\end{align*}
\]

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-endi, and mw-aasi are
straightforward, deriving from /mu-iimbi/, /mu-endi/, 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)  \[ u \rightarrow \emptyset / \_ \_ V^{[+\text{round}]} \quad \text{u-deletion} \]

We could also consider letting the glide formation rule apply and then explain the difference /mu-aasi/ \(\rightarrow\) /mw-aasi/ vs. /mu-oofusi/ \(\rightarrow\) /m-oofusi/ by subjecting derived /mw-oofusi/ to a rule deleting w before a round vowel.

(18)  \[ w \rightarrow \emptyset / [+\text{round}] \quad \text{w-deletion} \]

Thus we must keep in mind two hypotheses regarding /u+o/ and /u+u/ sequences.

**v-rounding.** Now consider class 2. In stems beginning with a vowel, we 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-oogo/, /w-oofusi/, and /w-uuci/ from /va-oogo/, /va-oofusi/, and /va-uutsi/. Application of ə-deletion would yield /v-oogo/, /v-oofusi/, and /v-uutsi/, which differ from the surface forms only in the replacement of v by w. Since this process takes place before a round vowel, we conjecture that there may be an assimilation rule such as the following.

(19)  \[ +\text{labial} \quad +\text{cont} \quad +\text{voice} \rightarrow [\text{cons}] / \_ \_ [+\text{round}] \quad \text{v-rounding} \]

If there is such a rule in the language, it would eliminate any sequences vɯ, vο: and the data contain 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 *[ooogofi]. Two explanations are available. One is that v-rounding is ordered after w-deletion, so at the stage where w-deletion would apply, this word has the shape /ooogofi/ and not /woogofi/ (so w-deletion cannot apply). The other is that (18) needs to be revised, so that it only deletes a postconsonantal w before a round vowel.

(20)  \[ [+\text{round}] \rightarrow \emptyset / C / [+\text{round}] \]

Our decision-making criteria are not stringent enough that we can definitively choose between these solutions, so we will leave this question open for the time being.

Moving to other classes, the nouns in class 3 present no problems. Glide formation applies to this prefix, so /mu-iina/ \(\rightarrow\) /mw-iina/, and before a
round vowel derived \(w\) deletes, so /mu-oooto/ \(\rightarrow\) mw-oooto which then becomes [m-oooto].

Front vowels and glides. The nouns in class 4 generally conform to the predictions of our analysis. Note in particular that underlying /mi-uu\(\mathring{n}\) and /mi-oooto/ undergo glide formation before a round vowel. Such examples show that it was correct to state the glide formation rule in a more general way, so that all high vowels (and not just /u/) become glides before any vowel (not just nonround vowels).

We cannot yet fully explain what happens with noun stems beginning with the vowel i, as in m-iina, m-iigiigi. Given /mi-iinal/, /mi-iigiigi/, we predict surface *mj-iina, *mj-iigiigi. This is reminiscent of the problem of /mu-oogo/ 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 mj-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.

\[
(21) \begin{bmatrix}
+ \text{high} \\
- \text{back} \\
- \text{syl}
\end{bmatrix} \rightarrow \emptyset / \begin{bmatrix}
+ \text{high} \\
- \text{back}
\end{bmatrix} \quad \text{j-deletion}
\]

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 it also appears as k(\(t\))- before i. Before other vowels, it appears as t', as in t'-uula, t'-aanga, t'-ooto, and t'-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 kj-uula, kj-aanga, kj-ooto, and kj-eenda, given glide formation. The discrepancy lies in the fact that the predicted sequence kj has been fused into t', a process of palatalization found in many languages. Since kj is nowhere found in the data, we can confidently posit the following rule.

\[
(22) \begin{bmatrix}
+ \text{cons} \\
- \text{syl} \\
+ \text{back} \\
- \text{cons} \\
- \text{voice} \\
- \text{back}
\end{bmatrix} \rightarrow [+\text{cor}] \emptyset
\]

Since /ki/ surfaces as [t\(\tilde{t}\)] when attached to a vowel-initial noun stem, the question arises as to what has happened in k-iiko, k-iina, and k-iigiigi. The glide formation rule should apply to /ki-iicol/, /ki-iinal/, and /ki,iigiigi/.
giving kj-iiho, kj-iina, and kj-iigiigi, which we would expect to undergo (22). But there is a rule deleting j before i. If j is deleted by that rule, it could not condition the change of k to t', so all that is required is the ordering statement that j-deletion precedes palatalization (22). Thus /ki-iina/ becomes kj-iina by glide formation, and before the palatalization rule can apply, the j-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 work, 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 3 and is discussed in more detail in chapter 8: 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 form 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 analyzing 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-iijooga, and w-aangufu from underlying /wu-eelu/, /wu-uumi/, /wu-oogofu/, /wu-iijooga/, and /wu-aangufu/. Applying glide formation would give the surface forms *ww-eelu, *ww-uumi, *ww-oogofu, *ww-iijooga, and *ww-aangufu, which differ from the surface form in a simple way, that they have two w’s where the actual form has only a single w, which allows us to posit the following degemination rule.

\[
\begin{align*}
\text{Glide Degemination} \\
\begin{array}{c}
\text{Glide Degemination} \\
\end{array}
\end{align*}
\]

6.2.4 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. Hehe 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)  

<table>
<thead>
<tr>
<th>V</th>
<th>V for</th>
<th>V for each</th>
<th>make V</th>
</tr>
</thead>
<tbody>
<tr>
<td>kúkama</td>
<td>kúkamíla</td>
<td>kúkamílaná</td>
<td>kúkamjá</td>
</tr>
<tr>
<td>kúsaná</td>
<td>kúsaníla</td>
<td>kúsanílaná</td>
<td>kúsanjá</td>
</tr>
<tr>
<td>kútová</td>
<td>kútovélá</td>
<td>kútovélána</td>
<td>kútovjá</td>
</tr>
<tr>
<td>kúlavá</td>
<td>kúlavíla</td>
<td>kúlavílaná</td>
<td>kúlavjá</td>
</tr>
<tr>
<td>kúfwiímá</td>
<td>kúfwiímíla</td>
<td>kúfwiímílaná</td>
<td>kúfwiímjá</td>
</tr>
<tr>
<td>kúkalaánɡá</td>
<td>kúkalaánɡíla</td>
<td>kúkalaánɡílaná</td>
<td>kúkalaánɡjá</td>
</tr>
<tr>
<td>kúkaláva</td>
<td>kúkalavíla</td>
<td>kúkalavílaná</td>
<td>kúkalavjá</td>
</tr>
<tr>
<td>kwéenda</td>
<td>kwéendélá</td>
<td>kwéendelána</td>
<td>kwéendjá</td>
</tr>
<tr>
<td>kwíimba</td>
<td>kwíimbíla</td>
<td>kwíimbílaná</td>
<td>kwíimbjá</td>
</tr>
<tr>
<td>kóogópa</td>
<td>kóogópélá</td>
<td>kóogópelána</td>
<td>kóogopjá</td>
</tr>
</tbody>
</table>

**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 exactly the same vowel. The stem of the word
for ‘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,’ -j- ‘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 →
[koogópa]); the sequence vo becomes wo (/ku-va-oogopa/ → kuwoogopa →
[kuwoogópa]). 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 Glide 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-il-a, kúsan-il-a, and kúfwim-il-a, but that vowel assimilates in height to a preceding mid vowel in examples such as kútov-il-a, kwéend-il-a, and kóogop-il-a. This motivates the following vowel harmony rule:

\[
V \rightarrow [\text{high}] / \left[ \begin{array}{c}
V \\
\text{C}\_0
\end{array} \right]
\]

Vowel Harmony

Regarding tone, most examples have an 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.

\[
V \rightarrow [\text{+H}] / \left[ \begin{array}{c}
\text{C}\_0
\end{array} \right] V
\]

tone assignment

In some verbs, this H is missing – see kúkama, kúsaná, kútová. Applying this tone assignment rule to these forms would result in outputs such as 'kúkáma, 'kúsaná, 'kútóva, with H tones on adjacent vowels. Since our examples contain no cases of consecutive H-toned vowels, we may assume a rule along the following lines.

\[
V \rightarrow [\text{+H}] / \left[ \begin{array}{c}
V \\
\text{C}\_0
\end{array} \right]
\]

What about the columns with the suffixes -j- ‘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 kúkalaángwá would be /kúkalaang-u-al/. 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.

\[\text{Such tone shift, where the tone of a vowel shifts to another vowel when the original vowel deletes or desyllabifies, is common in tone languages and is discussed in chapter 9.}\]

6.3 Fore

The next problem comes from Fore, spoken in Papua New Guinea.
6.3.1 The data

The following data motivate a set of phonological rules that apply in combinations of noun plus personal possessive affix. Your final goal is to identify the underlying forms of all roots and affixes, to discover the operative phonological rules, and order those rules.

(28)  
\[\begin{array}{cccc}
1\text{sg} & 2\text{sg} & 3\text{sg} & 1\text{pl} \\
tunte & tuka & tunkwa & tute \\
kajne & kajga & kajwa & kajre \\
ka:ne & ka:ka & ka:wa & ka:te \\
awnte & awka & awnkwa & awte \\
awne & awga & awwa & awre \\
pine & piwa & pire & 'shell' \\
ma?ne & ma:ka & ma:wa & ma:te \\
kone & koga & kowa & kore \\
aw?ne & awka & aw?wa & awte \\
inte & ika & inkwa & ite \\
na:nnte & na:ka & na:nkwa & na:te \\
agene & agega & agewa & agere \\
k?ne & koka & k?wa & kote \\
mune & muga & muwa & mure \\
awnte & awrka & awwnkwa & awrte \\
kajnte & kajka & kajnkwa & kajte \\
abe?ne & abeka & ab?wa & abete \\
\end{array}\]

6.3.2 Morphological analysis

Separating roots from suffixes in this language is difficult, since it is not obvious whether certain segments are part of the root and delete in one context, or are part of the suffix and delete in another context – or, are they epenthetic? Thus the root for ‘axe’ might be /tun/ or it might be /tu/ – if the former, some rule must delete /n/ in [tuka] ‘your sg axe’, if the latter, we would conclude that the 1sg and 3sg suffixes are /nte, -nkwa/. If we assume the suffixes /nte, -nkwa/, then we would need to explain why they appear as [-ne, -wa] after ‘clothes’ and ‘one.’ It almost seems that in order to get the answer to one question, you have to know the answer to all other questions.

The first step to solving this problem is to determine how many significant behavioral categories there are. By comparing the forms of ‘clothes’ and ‘eye,’ we can conclude that these two roots are identical in terms of behavior: the suffixes have the same shape after these two roots, and the following inflec- tional material is the same across the roots. We can also see that there are major differences in the form of the suffixes between ‘eye’ and ‘liver,’ although the roots look very similar and in half of the forms are exactly the same.

(29)  
\[\begin{array}{cccc}
1\text{sg} & 2\text{sg} & 3\text{sg} & 1\text{pl} \\
kajne & kajga & kajwa & kajre \\
awne & awga & awwa & awre \\
awnte & awka & awnkwa & awte \\
\end{array}\]
The data of (28) can be reordered by roots, according to the surface patterns of the apparent personal suffixes, and this reveals that there are three behavioral classes of roots.

(30)  
<table>
<thead>
<tr>
<th></th>
<th>1sg</th>
<th>2sg</th>
<th>3sg</th>
<th>1pl</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>kajne</td>
<td>kajga</td>
<td>kajwa</td>
<td>kajre</td>
</tr>
<tr>
<td></td>
<td>awne</td>
<td>awga</td>
<td>awwa</td>
<td>awre</td>
</tr>
<tr>
<td></td>
<td>pine</td>
<td>piga</td>
<td>piwa</td>
<td>pire</td>
</tr>
<tr>
<td></td>
<td>kone</td>
<td>koga</td>
<td>kowa</td>
<td>kore</td>
</tr>
<tr>
<td></td>
<td>agene</td>
<td>agega</td>
<td>agewa</td>
<td>agere</td>
</tr>
<tr>
<td></td>
<td>mune</td>
<td>muga</td>
<td>muwa</td>
<td>mure</td>
</tr>
<tr>
<td>b.</td>
<td>kaːne</td>
<td>kaːka</td>
<td>kaːwa</td>
<td>kaːte</td>
</tr>
<tr>
<td></td>
<td>maːne</td>
<td>maːka</td>
<td>maːwa</td>
<td>maːte</td>
</tr>
<tr>
<td></td>
<td>awːne</td>
<td>awːka</td>
<td>awːwa</td>
<td>awte</td>
</tr>
<tr>
<td></td>
<td>koːne</td>
<td>koːka</td>
<td>koːwa</td>
<td>kote</td>
</tr>
<tr>
<td></td>
<td>abeːne</td>
<td>abeːka</td>
<td>abeːwa</td>
<td>abete</td>
</tr>
<tr>
<td>c.</td>
<td>tunte</td>
<td>tuka</td>
<td>tunkwa</td>
<td>tute</td>
</tr>
<tr>
<td></td>
<td>awnte</td>
<td>awka</td>
<td>awnkwa</td>
<td>awte</td>
</tr>
<tr>
<td></td>
<td>inte</td>
<td>ika</td>
<td>inkwa</td>
<td>ite</td>
</tr>
<tr>
<td></td>
<td>naːnte</td>
<td>naːka</td>
<td>naːnkwa</td>
<td>naːte</td>
</tr>
<tr>
<td></td>
<td>arawnnte</td>
<td>arawka</td>
<td>arawnkwa</td>
<td>arawte</td>
</tr>
<tr>
<td></td>
<td>kajnte</td>
<td>kajka</td>
<td>kajnkwa</td>
<td>kajte</td>
</tr>
</tbody>
</table>

In (a), the invariance of the portion that precedes ne in the 1sg, ga in the 2sg, wa in the 3sg, and re in the 1pl suggests that these roots are /kaj, aw, pi, ko, age, mu/, further leading to the conclusion that the suffixes are /-ne/ ‘1sg’, /-gal/ ‘2sg’, /-wal/ ‘3sg’, /-rel/ ‘1pl’, or some phonologically similar form. Having identified the root–suffix boundary, we can now proceed with the phonological analysis of underlying forms and rules.

### 6.3.3 Phonological alternations

We concluded that the (a) subset of roots are underlyingly /kaj, aw, pi, ko, age, mu/ because those are the parts of words that invariantly correlate with the choice of a particular root. A further consequence of that conclusion is that the roots in (b) and (c), which behave differently, should have a significantly different-looking underlying form. The roots in (30b) have the surface realizations [kaː?, maː?, awʔ, koʔ, abeʔ] and [kaː:, maː:, aw, ko, abe]. The roots of (30a) underlyingly end in a glide or vowel, and since the roots in (30b) behave differently, those roots must not end in a vowel or glide, which leads to the conclusion that the roots of (30b) are /kaː?, maː?, awʔ, koʔ, abeʔ/, i.e. these roots end in a glottal stop.

Similar reasoning applied to the roots of (30c) leads to the conclusion that these roots are /tun, awn, in, naːn, arawn, kajn/. Again, the roots have two types of surface realization, and the alternative theory for (30c) that the roots are /tu, aw, i, naː, araw, kaj/ can be ruled out on the grounds that
this would incorrectly render the (a) and (c) roots indistinguishable. The distinguishing feature of the (c) roots is that they all end with a nasal.

Having sorted out the underlying forms of the roots, we can turn to the suffixes, drawing one representative from each phonological class of roots.

(31)  

<table>
<thead>
<tr>
<th></th>
<th>1sg</th>
<th>2sg</th>
<th>3sg</th>
<th>1pl</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>aw-ne</td>
<td>aw-ga</td>
<td>aw-wa</td>
<td>aw-re</td>
</tr>
<tr>
<td>b.</td>
<td>aw?-ne</td>
<td>aw-ka</td>
<td>aw?-wa</td>
<td>aw-te</td>
</tr>
<tr>
<td>c.</td>
<td>awn-te</td>
<td>aw-ka</td>
<td>awn-kwa</td>
<td>aw-te</td>
</tr>
</tbody>
</table>

One fact stands out from this organization of data, that while both the 1sg and 1pl suffixes have the variant [te] somewhere, these suffixes cannot be the same because they act quite differently. A second fact which can be seen from these examples is that the 1pl and 2sg suffixes are similar in the nature and context of their variation. Both alternate between a voiceless stop and a voiced consonant – we can suspect that [r] is the surface voiced counterpart of [t]. And the voiced alternant appears after roots which underlyingly end in a glide or a vowel, whereas the voiceless variant appears after an underlying nasal or a glottal stop.

Nasals and glottal stops have in common the fact of being [−continuant], and glides and vowels have in common the fact of being [+voice, −cons]. This gives rise to two theories regarding the underlying forms of the 2sg and 1pl and the rules that apply to those suffixes. First, we could assume /ga, re/ and the following rule to derive the voiceless variant.

(32)  

\[ +\text{cons} \rightarrow [−\text{voice}] / [−\text{cont}] \_ \]  Devoicing

Alternatively, we could assume /ka, te/ and the following voicing rule.

(33)  

\[ +\text{cons} \rightarrow [+\text{voice}] / [+\text{voice} − \text{nas}] \_ \]  Voicing

Either analysis is, at this point, entirely reasonable, so we must leave the choice between these analyses unresolved for the moment. We might reject (33) on the grounds that it requires specification of an additional feature, but such a rejection would be valid only in the context of two competing complete analyses which are empirically correct and otherwise the same in simplicity.

The 3sg suffix surfaces as [kwa] and [wa], the former after a nasal and the latter after an oral segment. That leads to two pairs of rule and underlying representation. If the underlying form of the suffix is /wal/ then there is a rule inserting [k] between a nasal and w.
If the suffix is underlyingly /kwa/, a rule deletes k after an oral segment before w.

\[
\begin{align*}
\text{34) } & \quad \emptyset \rightarrow \begin{bmatrix} +\text{high} \\ +\text{cons} \\ -\text{voice} \end{bmatrix} / [+\text{nas}] \rightarrow [+\text{rd}] -syl \quad \text{k-insertion} \\
\end{align*}
\]

Finally, the 1sg suffix might be /ne/ or it might be /te/. As noted above, we could rule out the possibility /te/ if we knew that the 1pl suffix is /te/. This means that a choice of /te/ for the 1s entails that the 1pl suffix is not /te/, therefore is /re/. If the 1sg suffix is /ne/, on the other hand, the 1pl could be either /te/ or /re/. If the 1sg suffix is /te/, then the following rule is required to derive the variant [ne].

\[
\begin{align*}
\text{35) } & \quad \begin{bmatrix} + \text{high} \\ + \text{cons} \\ - \text{voice} \end{bmatrix} \rightarrow \emptyset / [+\text{nas}] \rightarrow [+\text{rd}] -syl \quad \text{k-deletion} \\
\end{align*}
\]

If the suffix is /ne/ then the following rule derives the variant [te].

\[
\begin{align*}
\text{36) } & \quad \begin{bmatrix} + \text{cor} \\ - \text{voice} \end{bmatrix} \rightarrow [-\text{nas}] / [+\text{nas}] \quad \text{Nasalization} \\
\end{align*}
\]

Besides three rules which affect the initial consonant of the personal suffixes, a rule deletes root-final glottal stop and nasals. In comparing roots with deleted consonants, we see that both glottal stop and nasals delete in the same context: before the 2sg and 1pl suffixes (which we have determined are /ka, te/ or /ga, re/).

\[
\begin{align*}
\text{38) } & \quad \begin{array}{llll}
\text{1sg} & \text{2sg} & \text{3sg} & \text{1pl} \\
aw\text{-ne} & aw-ka & aw\text{-wa} & aw-te \\
awn-te & aw-ka & awn-kwa & aw-te \\
\end{array} \quad \begin{array}{l}
\text{‘skin’} \\
\text{‘liver’} \\
\end{array} \\
\end{align*}
\]

What phonological property unifies these two suffixes and distinguishes them from /ne – te/ and /kwa – wa/? A simple answer would be that these suffixes begin with voiceless stops – if we assume that the suffixes are /ne/ ‘1sg,’ /ka/ ‘2sg,’ /wə/ ‘3sg,’ and /te/ ‘1pl.’ We will pursue the consequences of that concrete decision about suffixes.

The choice of underlying forms for suffixes entails certain choices for rules: in this analysis, we are committed to Voicing (33), k-insertion (34), and Denasalization (37). The rule deleting root-final stops is as follows.

\[
\begin{align*}
\text{39) } & \quad [-\text{cont}] \rightarrow \emptyset / [-\text{voice}] \quad \text{Stop Deletion} \\
\end{align*}
\]

We must determine how these four rules are ordered. Although Voicing affects underlying voiceless stops after voiced oral segments, we see from
[awka] ‘your skin’ from /awʔka/ and [awka] ‘your liver’ from /awn-ka/ that Voicing precedes Stop Deletion.

The structural description of the latter rule is not satisfied in /awnka, awʔka/, hence Voicing does not apply. Subsequently, Stop Deletion applies to eliminate n and ? before a voiceless stop.

(40) /awʔ-ka/ underlying
NA Voicing
[awka] Stop Deletion

Stop Deletion obscures the Voicing rule, because it creates surface counterexamples to the prediction of Voicing that [k, t] should not follow a vowel or glide.

The ordering of k-insertion is also a matter of concern, since that rule inserts a voiceless stop but Stop Deletion is not triggered by inserted k. Underlying /awn-wa/ undergoes k-insertion to become [awnkwa], a form which satisfies the structural description of Stop Deletion (which would delete the nasal), yet the nasal is not deleted. This indicates that k-insertion follows Stop Deletion – k created by the former rule is not present when Stop Deletion applies.

We can also determine that Denasalization follows Stop Deletion, since the former rule creates a sequence of nasal plus stop – /awn-ne/ → [awn-te] ‘my liver’ – and Stop Deletion applies to a sequence of nasal plus stop – /awn-te/ → [awte] ‘our liver’ – yet Stop Deletion does not apply to the output of Denasalization. In summary, the rules of Fore which we have proposed, with their ordering, are as follows.

(33) [+cons] → [+voice] / [+voice] __Voicing

(39) [-cont] → ø / [+voice] Stop Deletion

(34) ø → [+ high] [+ cons] / [+nas] __ [+ rd] k-insertion

(37) [+nas] → [-nas] / [+nas] __ Denasalization

To be sure that our analysis works, derivations of relevant examples are given in (40).

(41) a. /aw-ne/ /aw-ka/ /law-wa/ /law-te/ underlying
awga awre awwa awre Voicing
[awne] [awga] [awwa] [awre]
6.3.4 Alternative analysis

Now that we have one analysis of the data, we need to consider alternatives, to determine if our analysis is the best one. Our basis for evaluating alternatives will be how they mesh into an integrated system – the individual rules themselves are not significantly different in terms of their simplicity. In constructing an alternative to be compared with our hypothesized account, we must construct the best analysis that we can.

One alternative to consider is that the 3sg suffix is underlying /kwa/, not /wa/, an assumption which would mean a rule of $k$-deletion rather than insertion. There is a fundamental incompatibility between this proposed underlying form and the theory that there is a stop-voicing rule applying to the affixes /te, kal/, since deletion of root-final stops applies in the latter case (/lain-ka/ $\rightarrow$ [aw-ka] ‘your liver’) but not the former (/lain-kwa/ $\rightarrow$ [awn-kwa] ‘his/her liver’). Under the theory that there is a $k$-deletion rule, we must assume the underlying suffixes /ga, re/, meaning that there is a devoicing rule, and Stop Deletion must be suitably reformulated so that only /ga, re/ trigger the rule, and /ne (te), kwa/ do not.

The hypothesized consonants that trigger Stop Deletion would be /g, r/, which can be distinguished from the consonants that do not trigger the rule in being [+voice, –nasal]. The added complication of specifying that the triggering consonant is [–nasal] is necessary only under the assumption that the 1sg suffix is /ne/; we can avoid that complication by assuming that the suffix is /te/, in which case the following alternative statement of stop deletion is necessitated by the alternative assumptions about underlying forms (/te, ga, kwa, re/).

\[
\begin{array}{cccc}
\text{b. } & \text{[aw?-ne]} & \text{[aw?-ka]} & \text{[aw?-wa]} & \text{[aw?-te]}\\
\text{NA} & \text{awka} & \text{[aw?wa]} & \text{awte} & \text{Voicing Stop Deletion}
\end{array}
\]

\[
\begin{array}{cccc}
\text{c. } & \text{[awn-ne]} & \text{[awn-ka]} & \text{[awn-wa]} & \text{[awn-te]}\\
\text{NA} & \text{awka} & \text{awnkwa} & \text{awte} & \text{Voicing Stop Deletion k-insertion Denasalization}
\end{array}
\]

Yet another possibility which preserves the underlying suffixes /ka, te/ is that $k$-deletion specifically requires a following w, therefore /kwa/ becomes /wa/ but /ka/ remains unchanged. Such a complication in the $k$-deletion rule is sufficient to cause us to reject that analysis.

\((42)\) \ [-cont] $\rightarrow$ Ø / __ [+voice] Stop Deletion (alternative version)\n
Given these alternative underlying forms, the variant [ne] of the 1sg suffix found in [aw-ne] ‘my eye’ and [aw?-ne] ‘my skin’ (but not [awn-te] ‘my liver’) can be accounted for by the following nasalization rule.

\[(43)\] \ [-voice] $\rightarrow$ [+nasal] / [–nasal] V Nasalization
The reason for specifying that a following vowel is required is so that the suffix /kwa/ does not undergo the rule.

To summarize the alternative analysis, we might instead assume the suffixes /te, ga, kwa, re/, and the following rules.

\[(40) \begin{array}{c}
\neg \text{voice} \rightarrow \text{+nasal} / \neg \text{nasal} \rightarrow \text{V} \\
\end{array}\]
\text{Nasalization}

\[(32) \begin{array}{c}
\text{+cons} \rightarrow \neg \text{voice} / \neg \text{cont} \\
\end{array}\]
\text{Post-stop Devoicing}

\[(39) \begin{array}{c}
\neg \text{cont} \rightarrow \text{Ø} / \text{+voice} \\
\end{array}\]
\text{Stop Deletion}

\[(35) \begin{array}{c}
\text{+ high} \\
\text{+ cons} \\
\neg \text{voice} \\
\rightarrow \text{Ø} / \neg \text{nas} \\
\text{rd} \\
\neg \text{syl} \\
\end{array}\]
\text{k-deletion}

There is a fatal flaw in the alternative analysis, centering around the interaction of Devoicing and Stop Deletion. The suffixes which condition Stop Deletion are underlyingly [+voice], but that consonant is also subject to Devoicing – by the stop which is deleted. If Stop Devoicing applies first, then /awn-ga/ becomes awnka, and Stop Deletion cannot apply since only voiced consonants trigger the rule – *[awnka] rather than [awka] would result. On the other hand if Stop Deletion applies first, then /awn-ga/ does undergo Stop Deletion to become awga, but then the consonant needed to trigger Devoicing no longer exists, and *[awga] results. Thus the hypothesized rules cannot be ordered in a manner that gives the correct output, meaning that the rules are wrong. On those grounds, the alternative analysis must be rejected.

### 6.4 Modern Hebrew

The next case study comes from a set of alternations in the conjugation of verbs in a certain derivational class in Modern Hebrew.

#### 6.4.1 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. The data to be accounted for are in (44).

\[(44) \begin{array}{c}
1\text{sg} \quad 2\text{sg mas} \quad 3\text{sg fem} \\
\text{Related word} \\
it\text{parnasti} \quad it\text{parnes} \quad it\text{parnesu} \quad \text{‘earn’} \\
it\text{parsamti} \quad it\text{parsem} \quad it\text{parsemu} \quad \text{‘become famous’} \\
\text{idbalbalti} \quad \text{idbalbel} \quad \text{idbalbelu} \quad \text{‘be confused’} \\
\text{idgalgalti} \quad \text{idgalgel} \quad \text{idgalgelu} \quad \text{‘revolve’} \\
\text{idhamakti} \quad \text{idhamek} \quad \text{idhamku} \quad \text{‘turn away’} \\
\text{itlabaʃ} \quad \text{itlabeʃ} \quad \text{itlapʃu} \quad \text{‘get dressed’} \\
\end{array}\]
6.4.2 Morphological analysis

Each of these verbs has a prefix which is either /it/ or /id/, and the prefix transparently surfaces as one of these two variants in most examples. The first-person-singular form is marked with a suffix -ti, the third-singular feminine has the suffix -u, and the second-singular masculine 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 ʃ newspart/ improve’ and ʃpur ‘improvement,’ have in common a set of consonants, but their vowels differ (vowel changes are a means of indicating derivational relations in Semitic languages, which we will not be concerned with).

6.4.3 Phonological alternations

Voicing assimilation. As for the choice between an underlying voiced or voiceless consonant in the prefix, 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

<table>
<thead>
<tr>
<th>verb</th>
<th>verb</th>
<th>verb</th>
<th>meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>idbadarti</td>
<td>idbadr</td>
<td>idbadru</td>
<td>‘make fun’</td>
</tr>
<tr>
<td>idgara’ti</td>
<td>idgar’</td>
<td>idgar’u</td>
<td>‘divorce’</td>
</tr>
<tr>
<td>itpalalti</td>
<td>itpalal</td>
<td>itpalalu</td>
<td>‘pray’</td>
</tr>
<tr>
<td>itxamamti</td>
<td>itxamem</td>
<td>itxamenu</td>
<td>‘warm’</td>
</tr>
<tr>
<td>itmotati</td>
<td>itmotet</td>
<td>itmotetu</td>
<td>‘quake’</td>
</tr>
<tr>
<td>itʔoja’ti</td>
<td>itʔojej’</td>
<td>itʔojej’u</td>
<td>‘recover’</td>
</tr>
<tr>
<td>idbodati</td>
<td>idboded</td>
<td>idbodedu</td>
<td>‘seclude oneself’</td>
</tr>
<tr>
<td>istaparti</td>
<td>istapru</td>
<td></td>
<td>‘get a haircut’</td>
</tr>
<tr>
<td>istarakti</td>
<td>istarek</td>
<td>istarku</td>
<td>‘comb hair’</td>
</tr>
<tr>
<td>iʔtalamp</td>
<td>iʔtalme</td>
<td>iʔtalme</td>
<td>‘improve’</td>
</tr>
<tr>
<td>izdakanti</td>
<td>izdaken</td>
<td>izdaknu</td>
<td>‘age’</td>
</tr>
<tr>
<td>izdarasti</td>
<td>izdarez</td>
<td>izdarzu</td>
<td>‘hurry’</td>
</tr>
<tr>
<td>itamamti</td>
<td>itamem</td>
<td>itamemu</td>
<td>‘feign innocence’</td>
</tr>
<tr>
<td>idardarti</td>
<td>idarder</td>
<td>idarderu</td>
<td>‘decline’</td>
</tr>
<tr>
<td>idtapa’hti</td>
<td>idtapa’eh</td>
<td>idtaphu</td>
<td>‘develop’</td>
</tr>
<tr>
<td>idgalalhti</td>
<td>idgaleah</td>
<td>idgalhu</td>
<td>‘shave’</td>
</tr>
<tr>
<td>itnat’æhti</td>
<td>itnat’æeh</td>
<td>itnat’hu</td>
<td>‘argue’</td>
</tr>
<tr>
<td>iʔtagati</td>
<td>iʔtaga</td>
<td>iʔtaga’u</td>
<td>‘become mad’</td>
</tr>
<tr>
<td>itparati</td>
<td>itpara</td>
<td>itpar’u</td>
<td>‘cause disorder’</td>
</tr>
<tr>
<td>itmaleti</td>
<td>itmale</td>
<td>itmal’u</td>
<td>‘become full’</td>
</tr>
<tr>
<td>itapa’hti</td>
<td>itpale</td>
<td>itpal’u</td>
<td>‘become surprised’</td>
</tr>
<tr>
<td>itnasati</td>
<td>itnase</td>
<td>itnas’u</td>
<td>‘feel superior’</td>
</tr>
</tbody>
</table>
the voiceless consonant \( [t] \), so we assume that the prefix is underlingly \( /it/ \). Before a voiced obstruent, a voiceless obstruent becomes voiced.

(45) \[-\text{sonorant}] \rightarrow [+\text{voice}] / \_ \_ C
    \_ \_ C

Alternations in V2. The second vowel of the stem has three phonetic variants: \([a]\) as in \( \text{itparnasti} \), \([e]\) as in \( \text{itparnes} \), and \( \emptyset \) as in \( \text{idbadru} \) (cf. \( \text{idbadre} \)). 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 first- and second-person-singular masculine forms (with the suffixes \(-\text{it}\) and \(-\emptyset\)) 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

\begin{array}{llll}
\text{itham\_ku} & \text{itlap\_fu} & \text{idbad\_ru} \\
\text{idgar\_fu} & \text{istap\_ru} & \text{istar\_ku} \\
\text{\( i\)itap\_ru} & \text{it\( ^{t}\)al\_mu} & \text{idzak\_nu} \\
\text{idzar\_zu} & \text{itmal\_\( u\)} & \text{itpal\_\( u\)} \\
\text{itnas\_\( u\)} & \text{itpat\_hu} & \text{idgal\_hu} \\
\text{itnat\( ^{a}\)\_hu} & \text{it\( ^{t}\)ag\_\( u\)} & \text{itpar\_\( u\)}
\end{array}

No vowel deletion

\begin{array}{llll}
\text{itparn\( e\)su} & \text{itpars\( e\)mu} & \text{idbale\( g\)lu} \\
\text{idgal\( g\)elu} & \text{idard\( e\)ru} & \text{itpale\( g\)lu} \\
\text{ixam\( e\)mu} & \text{itmot\( e\)tu} & \text{id\( o\)ge\( f\)u} \\
\text{idbode\( du\)} & \text{itam\( e\)mu}
\end{array}

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 \( \text{it\( ?\)oge\( f\)u} \) 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 “\( C_i \ldots C_j \)” in the rule).

(47) \( e \rightarrow \emptyset / V \_ C_i \_ C_j V \)
At this point, we now clearly 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 data set, we find \[a\] before CC (\textit{itparnasti}), and \[e\] before C\# or CV (\textit{itparnes}, \textit{itparnesu}). Assuming that this distribution is generally valid, we would therefore posit the following rule to derive \[a\] from /\textit{e}/.

\[(48) \ e \rightarrow \ a / _{ \_ } \text{CC} \]

An attempt to derive \[e\] from underlying /\textit{a}/ runs into the difficulty that the context “when followed by C\# or CV” is not a coherent context, but is just a set of two partially related contexts. This motivates the decision to select underlying /\textit{e}/.

In four examples, the second stem vowel /\textit{e}/ appears as \[a\] before a single consonant, namely the first-person-singular forms \textit{itmotatti}, \textit{idbodati}, \textit{if\textsc{fi}gat\textsc{ti}} and \textit{itparatti}. These examples fall into two distinct subgroups, as shown by looking at their underlying stems, which is revealed in the third-singular feminine forms (\textit{itmotet-u}, \textit{idboded-u} and \textit{if\textsc{fi}gast\textsc{u}}, \textit{itpar\textsc{s}u}). In the first two examples the stems underlyingly end in a coronal stop \textit{t} or \textit{d}, and in the second two examples the stems underlyingly end in the voiced pharyngeal \textit{t}. At the underlying level, the second stem vowel is followed by two consonants (\textit{itmotet\textsc{ti}}, \textit{idboded\textsc{ti}}, \textit{if\textsc{fi}gast\textsc{ti}}, and \textit{itpar\textsc{s}t\textsc{ti}}). 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 (\textit{itmotatti} and \textit{idbodati} from /\textit{itmotat-ti}/ and /\textit{idbodad-ti}/) combination of the first-singular suffix with the root would (after assimilation of voicing) be expected to result in *\textit{itmotatti} and *\textit{idbob\textsc{d}att\textsc{i}}. In fact, the data provide no examples of geminate consonants, and where geminates might have been created by vowel syncope in \textit{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.

\[(49) \ C_iC_i \rightarrow C_i \]

This rule also explains \textit{itamem} and \textit{idarder}, where the stem begins with /\textit{t}/ or /\textit{d}/. The underlying forms would be /\textit{it-tamem}/ and /\textit{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 /\textit{f\textsc{age}t}/ and /\textit{pare\textsc{t}}/ will be left aside temporarily. We thus turn to the stems represented in \textit{itpatah\textsc{ti}}, \textit{idgalah\textsc{ti}}, and \textit{in\textsc{na}t\textsc{a}htar\textsc{ti}}. What is problematic about these stems is the appearance of [ea] when no suffix is added, viz. \textit{ipate\textsc{ah}}, \textit{idgale\textsc{ah}}, and \textit{in\textsc{na}t\textsc{a}h}. Assuming the underlying forms to be \textit{itpah}, \textit{idgalah}, and \textit{ina\textsc{fe}t\textsc{h}} (selecting /\textit{e}/ as the second vowel, analogous to \textit{itpar\textsc{nes}},...
itlabeʃ, and idboded), we would need a rule inserting the vowel [a]. These stems have in common that their final consonant is the pharyngeal [h], suggesting a rule along the following lines.

\[(50) \quad \emptyset \rightarrow a / e_\_ h\]

Why does this rule only apply in the suffixless second-singular masculine form? When the stem is followed by -u (iitpatehū → iitpathu) the vowel /e/ is deleted by the syncope rule, so there is no vowel before h. Syncope does not apply before the suffix -ti in /iitpatehtī → iitpatahī 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 fageʕ and pareʕ, we can see that this same process of vowel insertion applies in these stems in the second-singular masculine. Starting from /iʃtagēʕ/ and /itpareʕ/, vowel epenthesis obviously applies to give intermediate /iʃtaeγeʕ/ and /itpareaʕ/. This argues that the epenthesis rule should be generalized so that both of the pharyngeal consonants trigger the process.

\[(51) \quad \emptyset \rightarrow V / e_\_ C\]

\([+\text{Low}] \quad [+\text{Low}]\]

The forms derived by (51) are close to the actual forms, which lack the consonant ʕ, and 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 indicate 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.

\[(52) \quad ʕ \rightarrow \emptyset / C,\#\] \(\rightarrow\) \(ʕ \rightarrow \emptyset / .\)

No further rules are needed to account for this set of examples. In iftagati and itparati, from ifiʃageʕti 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, iftagati and itparati are parallel to itpateah, idgaleah, and imtaʔeah. The nonparallelism derives from the fact that syllable-final ʕ is deleted, so predicted *iftagaʕti and *itparaʕti are realized as iftagati and itparati thanks to this deletion.

The final set of verb stems typified by the verb itmaleti ~ itmale ~ imalʔu exhibit a glottal stop in some contexts and \(\emptyset\) 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, so
we will explore both. 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 $\emptyset$. A crucial difference between stems ending in $\emptyset$ and stems presumably ending in $\emptyset$ is that the stem vowel /e/ does not lower to [a] before -ti in the latter set. Thus, deletion of $\emptyset$ would have to be governed by a different rule than deletion of $\emptyset$, since $\emptyset$-deletion precedes lowering and $\emptyset$-deletion follows lowering.

An alternative possibility that we want to consider is that these stems really end in a vowel, not a 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.

\[
\begin{array}{lll}
\text{istaparti} & \text{‘get a haircut’} & \text{istaraki} & \text{‘comb hair’} \\
\text{iʃtaparti} & \text{‘improve’} & \text{it$'$alamti} & \text{‘have photo taken’} \\
\text{izdakanti} & \text{‘age’} & \text{izdarasti} & \text{‘hurry’}
\end{array}
\]

We would have expected forms such as [itsaparti], [iʃaparti], [itt$'$alamti] by just prefixing it- to the stem. A metathesis rule is therefore needed which moves $t$ after the stem-initial consonant. What makes this group of consonants – [s, ſ, t, z] – a natural class is that they are all and the only strident coronals. We can thus formalize this rule as follows: a coronal stop followed by a coronal strident switch order.

\[
\begin{array}{l}
\left[+\text{cor}\right]_{-\text{cont}} +\text{cor} +\text{strid} \rightarrow +\text{cor} +\text{strid} +\text{cor} +\text{cont}
\end{array}
\]

The ordering of this metathesis rule with respect to the voicing assimilation rule is crucial. Given underlying /it-zakanti/, you might attempt to apply metathesis first, which would yield ıztakanti, 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 įstakanti. So if metathesis applies before voicing assimilation, we will derive an incorrect result, either įztakanti if there is no voicing assimilation (assuming that the rule only turns voiceless consonants into voiced ones) or įstakanti 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.
6.5 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.

6.5.1 The data

The relevant data are given in (55).

(55) Present Negative Volitional Past Inchoative
neru nenai netai neta nejo: ‘sleep’
miru minai mitai mita mio: ‘see’
ʃinu ʃinanai ʃinitai ʃinda ʃino: ‘die’
jomu jomanai jomitai jonda jomo: ‘read’
jobu jobanai jobitai jonda jobo: ‘call’
kat’u katanai kat’itai katta kato: ‘win’
kasu kasanai kaʃita kaʃita kaso: ‘lend’
waku wakanai wakitai waita wako: ‘boil’
t’ugu t’uganai t’ugitai t’uida t’ugo: ‘pour’
karu karanai karitai katta karo: ‘shear’
kau kawanai kaitai katta kao: ‘buy’

6.5.2 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 -jo: “inchoative”: that analysis seems reasonable given the 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, ʃin, jom, job, kat’, kas, wak, t’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: it is important to understand the literal predictions of your analysis, and to compare them with the observed facts.

(56) Predicted surface forms
Present Negative Volitional Past Inchoative
ner-u ner-nai ner-tai ner-ta ner-jo:
mir-u mir-nai mir-tai mir-ta mir-jo:
ʃin-u ʃin-nai ʃin-tai ʃin-ta ʃin-jo:
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 is. It is no surprise that the present-tense forms would be 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 highly 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 those 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* (*fınanaı, jomanaı, jobanaı, 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* was 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* (*fınitaı, jomitaı, jobitaı, and so on*), so this vowel might analogously be part of the suffix.

One 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 *fınitaı* versus *fında*, *jomitaı* versus *yonda*, *kaɾ'itaı* versus *katta*, *karitaı* versus *katta* (there are similarities such as *kaɾitaı* and *kaɾta* 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 assume that the volitional and past-tense suffixes differ solely by the presence of final *i*.

It is this realization, that there is a thorough 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, -*fıtai* vs. -*fıtta*, but how differently they behave phonologically, 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 /-ita/ and the past tense is /ta/. Because the negative acts very much like the volitional in terms of where it has a vowel, we also adopt the alternative that the negative 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**

<table>
<thead>
<tr>
<th>Present</th>
<th>Negative</th>
<th>Volitional</th>
<th>Past</th>
<th>Inchoative</th>
</tr>
</thead>
<tbody>
<tr>
<td>ner-u</td>
<td>ner-anai</td>
<td>ner-itai</td>
<td>ner-ta</td>
<td>ner-jo:</td>
</tr>
<tr>
<td>mir-u</td>
<td>mir-anai</td>
<td>mir-itai</td>
<td>mir-ta</td>
<td>mir-jo:</td>
</tr>
<tr>
<td>fin-u</td>
<td>fin-anai</td>
<td>fin-itai</td>
<td>fin-ta</td>
<td>fin-jo:</td>
</tr>
<tr>
<td>jom-u</td>
<td>jom-anai</td>
<td>jom-itai</td>
<td>jom-ta</td>
<td>jom-jo:</td>
</tr>
<tr>
<td>job-u</td>
<td>job-anai</td>
<td>job-itai</td>
<td>job-ta</td>
<td>job-jo:</td>
</tr>
<tr>
<td>kast-u</td>
<td>kast-anai</td>
<td>kast-itai</td>
<td>kast-ta</td>
<td>kast-jo:</td>
</tr>
<tr>
<td>kas-u</td>
<td>kas-anai</td>
<td>kas-itai</td>
<td>kas-ta</td>
<td>kas-jo:</td>
</tr>
<tr>
<td>wak-u</td>
<td>wak-anai</td>
<td>wak-itai</td>
<td>wak-ta</td>
<td>wak-jo:</td>
</tr>
<tr>
<td>tug-u</td>
<td>tug-anai</td>
<td>tug-itai</td>
<td>tug-ta</td>
<td>tug-jo:</td>
</tr>
<tr>
<td>kar-u</td>
<td>kar-anai</td>
<td>kar-itai</td>
<td>kar-ta</td>
<td>kar-jo:</td>
</tr>
<tr>
<td>ka-u</td>
<td>ka-anai</td>
<td>ka-itai</td>
<td>ka-ta</td>
<td>ka-jo:</td>
</tr>
</tbody>
</table>

Implicitly, we know that forms such as predicted "[kast’anai] (for [katanai]) and "[kas-itai] (for [kaʃ’tai]) must be explained, either with other changes in underlying 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 data set which, by hypothesis, have roots ending in r.

(58)  **Present Negative Volitional Past Inchoative**

| ner-u   | ne-nai | ne-tai | ne-ta | ne-jo:  | ‘sleep’ |
| mir-u   | mi-nai | mi-tai | mi-ta | mi-jo:  | ‘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 surfaces in most of the surface forms of the verb meaning ‘shear,’ whereas r only appears in verbs ‘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 the word for ‘shear’ is underlyingly /kar/. Now suppose we change our assumption about these two verbs, and assume that /ne/ and /mi/ end in vowels.
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.

### 6.5.3 Phonological rules

Since we have made reasonable progress in solving the problem of underlying forms, 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 segment is placed in square brackets; segments whose phonetic quality differs from the predicted quality are italicized.

### Modified predicted surface forms

<table>
<thead>
<tr>
<th>Present</th>
<th>Negative</th>
<th>Volitional</th>
<th>Past</th>
<th>Inchoative</th>
</tr>
</thead>
<tbody>
<tr>
<td>ne-u</td>
<td>ne-anai</td>
<td>ne-itai</td>
<td>ne-ta</td>
<td>ne-jo:</td>
</tr>
<tr>
<td>mi-u</td>
<td>mi-anai</td>
<td>mi-itai</td>
<td>mi-ta</td>
<td>mi-jo:</td>
</tr>
<tr>
<td>ʃin-u</td>
<td>ʃin-anai</td>
<td>ʃin-itai</td>
<td>ʃin-ta</td>
<td>ʃin-jo:</td>
</tr>
<tr>
<td>jom-u</td>
<td>jom-anai</td>
<td>jom-itai</td>
<td>jom-ta</td>
<td>jom-jo:</td>
</tr>
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<td>job-u</td>
<td>job-anai</td>
<td>job-itai</td>
<td>job-ta</td>
<td>job-jo:</td>
</tr>
<tr>
<td>kat^3-u</td>
<td>kat^3-anai</td>
<td>kat^3-itai</td>
<td>kat^3-ta</td>
<td>kat^3-jo:</td>
</tr>
<tr>
<td>kas-u</td>
<td>kas-anai</td>
<td>kas-itai</td>
<td>kas-ta</td>
<td>kas-jo:</td>
</tr>
<tr>
<td>wak-u</td>
<td>wak-anai</td>
<td>wak-itai</td>
<td>wak-ta</td>
<td>wak-jo:</td>
</tr>
<tr>
<td>t^4ug-u</td>
<td>t^4ug-anai</td>
<td>t^4ug-itai</td>
<td>t^4ug-ta</td>
<td>t^4ug-jo:</td>
</tr>
<tr>
<td>kar-u</td>
<td>kar-anai</td>
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<td>kar-ta</td>
<td>kar-jo:</td>
</tr>
<tr>
<td>ka-u</td>
<td>ka-anai</td>
<td>ka-itai</td>
<td>ka-ta</td>
<td>ka-jo:</td>
</tr>
</tbody>
</table>

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.

### Modified predicted surface forms

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<th>Negative</th>
<th>Volitional</th>
<th>Past</th>
<th>Inchoative</th>
</tr>
</thead>
<tbody>
<tr>
<td>ne[r]u</td>
<td>ne(a)nai</td>
<td>ne(i)tai</td>
<td>‘sleep’</td>
<td></td>
</tr>
<tr>
<td>mi[r]u</td>
<td>mi(a)nai</td>
<td>mi(i)tai</td>
<td>‘see’</td>
<td></td>
</tr>
<tr>
<td>ʃinTa</td>
<td>ʃin(j)jo:</td>
<td>‘die’</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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 column. 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, these two clusters are 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 \( j \) after a consonant.

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. Armed with this rule, we have accounted for a very large chunk of otherwise problematic examples in (60) – 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 want to consider what V-V sequences are found in the data. The sequence [ai] exists in the volitional and negative suffixes, and in past-tense waita; also [ui] in the past of the word for ‘pour’; also the sequences [ao:] and [au] in the verb ‘buy.’ We do not find sequences of vowels with the front vowels...
[e] or [i] plus a vowel ([ia], [ii], [ea], and [ei]). Therefore, we posit the following rule of vowel deletion.

\[
V \rightarrow \emptyset \left[+\text{syl}\right] \left[-\text{back}\right]\]

This resolves many problematic forms of the verbs ‘sleep’ and ‘die,’ such as the change /ne-itai/ → [netai], but there are still examples that we cannot explain. In the present tense, we find [neru] and [miru], which we presume derive 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 restrict the rule to exclude round vowels from deletion. Alternatively, /u/ fails to be deleted in /ne-u/; perhaps a consonant is inserted thereby eliminating the cluster of vowels.

\[
\emptyset \rightarrow r \left[+\text{syl}\right] \left[-\text{back}\right] V
\]

Armed with these new rules, we will have actually accounted for all forms of the verbs ‘sleep’ and ‘see.’

**Nasal + consonant.** The remaining problems have been reduced to a very small set. A comparison of presumed underlying and surface past forms is given below.

(64)  
- /ʃinta/  
- /ʃinda/  
- /jomta/  
- /jonda/  
- /jobta/  
- /jonda/  
- /katʰta/  
- /katta/  
- /kastʰa/  
- /kaʃta/  
- /wakta/  
- /waita/  
- /tʰugta/  
- /tʰuida/  
- /karta/  
- /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 [ʃinda] from /ʃinta/, where /t/ becomes voiced after a nasal. A process of postnasal voicing is rather common in the languages of the world, so we may hypothesize that there is such a process in Japanese.

(65)  
C \rightarrow [+\text{voice}] / [+\text{nasal}] _

The data further suggest that the rule applies in other examples, since we see that in the past tense [jonda] of the roots /jom/ and /job/, the final consonant of the root is a nasal on the surface, and /t/ becomes voiced.

We will consider another possibility later, that the present suffix is /ru/, so rather than inserting it in neru, we delete it in [jomu].
We account for the stems /job/ and /jom/ 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]).

\[(66) \quad [- \text{coronal}] \rightarrow \begin{array}{c} + \text{coronal} \\ + \text{nasal} \end{array} / \_C \]

Although the data only illustrate nasalization before /t/, (66) is stated as generally as possible, predicting that /k/ or /d/ would nasalize as well.

Watching for contexts where a phenomenon seems to be relevant to more than one form, we also notice that the surface forms [waita] and [tsuida] differ from their underlying forms /wakta/ and /t'ugta/ by replacing the preconsonantal velar with the vowel [i], suggesting a vocalization rule such as the following.

\[(67) \quad C \quad V \rightarrow [+\text{high}] \rightarrow [-\text{back}] / \_C \]

This rule accounts for [waita], and almost accounts for [t'uida]: but 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 /t'ugta/. We know that /t/ voices in another context, after a nasal, so we could account for voicing in [t'uida] by restating 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 [t'uida], 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 noncoronals 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.

### 6.5.4 Taking stock

We should review the analysis to be sure there are no loose ends. We have six rules – j-deletion, vowel deletion, r-insertion, consonant voicing, velar vocalization, and labial nasalization – which, given our assumptions regarding roots and suffixes, account for most of the forms in the data set. It is important to recheck the full data set 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 meaning ‘win’ (kat-u, kat-anai-anai, kat-itai, kat-ta, kat-o). Second, we have not accounted for the variation between s and j 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 why in the inchoative form [kao:] the suffix consonant j deletes.

**Correcting the final consonant.** The first problem to tackle is the variation in the final consonant of the verb ‘win.’ Looking at the correlation between the phonetic realization of the consonant and the following segment, we see that [ts] appears before [u], [tʃ] appears before [i], and [t] appears elsewhere. 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/ (so nothing more needs to be said about the surface forms kat-anai, kat-ta, and kat-o). Looking more generally at the distribution of [tʃ] and [ts] in the data, [tʃ] only appears before [i], and [ts] only appears before [u], allowing us to posit the following rules.

\[(68) \ t \rightarrow [+\text{del.rel}] / _ {u} \]

\[(69) \ t \rightarrow +\text{del.rel} _ {\text{ant}} / _ {i} \]

Moving to the word for ‘lend,’ we find a related problem that /s/ appears as [ʃ] before [i]. This is reminiscent of the process which we assumed turning t into tʃ before i. In fact, we can decompose the process t → tʃ into two more basic steps: /t/ becomes an affricate before [i], and s and tʃ become alveopalatal [ʃ] and [tʃ] before the vowel [i].

**i-epenthesis.** All that remains to be explained about the word for ‘lend’ is why [i] appears in the past tense, i.e. why does /kasta/ become kasita (whence [kəʃita])? 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.

\[(70) \ Ø \rightarrow [+\text{son}] / +\text{cont} _ {\text{cor}} _ {\text{cont}} _ {\text{high}} _ {\text{back}} \]

**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 [j] 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 /w/ to /t/. We can generalize this rule to applying to both /w/ and /w/, which are oral sonorants. Finally, positing underlying /kaw/ helps to resolve the mystery of why [j] deletes in the inchoative form [kao:], when otherwise [j] only deletes when it is preceded by a consonant. If we start with /ka-jo:/ there is no reason for [j] to delete, but if we start with /kaw-jo:/, [j] is underlingly preceded by a consonant /w/, which causes deletion of [j], 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 we do 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.

$$w \rightarrow \emptyset / \left[\begin{array}{c} +\text{syl} \\ -\text{low} \end{array}\right]$$

At this point, we have a complete analysis of the data. The rules (in shorthand versions) and underlying forms are recapitulated below.


Suffixes: -u ‘present,’ -anai ‘negative,’ -itai ‘volitional,’ -ta ‘past,’ -jo: ‘inchoative’

Rules:

- j → \(\emptyset / C\) _ 
- V → / e, i _ 
- \(\emptyset \rightarrow r / e, i / V\) [-round] 
- b, m → n / _t 
- k, g → i / _t 
- t → \(t^i / _u, i\) 
- \(t^i, s \rightarrow t^j, j / _i\) 
- \(\emptyset \rightarrow i / s / _t\) 
- r, w → t / _t 
- w → \(\emptyset / _V\) 
- t → d / C _ 
- [lo] [+voi]

**Progress by hypothesis forming and testing.** Three important points have emerged as our analysis developed. First, analysis proceeds 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 work 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.

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: the suffix might be /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 which is 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 nonround vowels delete after [e] and [i]: we made that assumption only because /ne-u/ and /mi-u/ apparently did not undergo the process of vowel deletion.

Any change in assumed underlying forms requires a reconsideration of those parts of the analysis relevant to that morpheme. We would then assume the underlying forms /ʃin-ru/, /jom-ru/, /kat-ru/, and so on, with the root-final consonant being followed by /r/. This /r/ must be deleted: but notice that we already have a rule which, stated in a more general form, would delete this /r/, namely the rule deleting /j/ after a consonant.

(74) [+sonor] → Ø / C _

If we generalize that rule to apply to any sonorant consonant after a consonant, we eliminate the rule of r-insertion, and generalize the rules j-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 conceive of and evaluate 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 some accents or stresses are omitted. The language has both underlying stresses whose position cannot be predicted – these are not marked in the transcriptions – and a predictable “mobile” stress which is assigned by rule – these are the stresses indicated here. Your analysis should account for how stress is assigned in those words marked with a rule-governed stress: you should not try to write a rule that predicts whether a word has a stress assigned by rule versus an underlying stress. Ignore the stress of words with no stress mark (other parts of the phonology of such words must be accounted for). Past-tense verbs all have the same general past-tense suffix, and the difference between masculine, feminine, and neuter past-tense involves the same suffixes as are used to mark gender in adjectives.

Adjectives

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Standard Ukrainian has palatalized and nonpalatalized consonants, but only nonpalatalized consonants before e. Consonants are generally palatalized before i, with some apparent exceptions such as bil ‘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. Also for masculine nouns referring to persons, ov/ev is inserted between the root and the case suffix in the locative singular (see words for ‘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

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Verbs

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### Doing an analysis

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### 3 Somali

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 you could analyze 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.

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<td>dano</td>
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<td>saano</td>
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<tr>
<td>nirig</td>
<td>ningta</td>
<td>nirgo</td>
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<tr>
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<td>gaj'ada</td>
<td>gab'do</td>
</tr>
<tr>
<td>hoyol</td>
<td>hoyo'la</td>
<td>hoglo</td>
</tr>
<tr>
<td>bayal</td>
<td>bayal'a</td>
<td>baglo</td>
</tr>
<tr>
<td>wahan</td>
<td>wa'barta</td>
<td>waharo</td>
</tr>
</tbody>
</table>
Provide a complete account of the following phonological alternations in Latin, including underlying forms for noun stems.

<table>
<thead>
<tr>
<th>Nominative</th>
<th>Genitive</th>
</tr>
</thead>
<tbody>
<tr>
<td>arks</td>
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<tr>
<td>dukis</td>
<td>dukis</td>
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<td>daps</td>
<td>dapis</td>
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<td>rekis</td>
<td>rekis</td>
</tr>
<tr>
<td>falanks</td>
<td>falangis</td>
</tr>
<tr>
<td>filiks</td>
<td>filikis</td>
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<tr>
<td>lapis</td>
<td>lapidis</td>
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<tr>
<td>lis</td>
<td>listis</td>
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<td>fraws</td>
<td>frawdis</td>
</tr>
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<td>noks</td>
<td>noktis</td>
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<td>frontis</td>
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<td>frons</td>
<td>frondis</td>
</tr>
<tr>
<td>inkurs</td>
<td>inkudis</td>
</tr>
<tr>
<td>sors</td>
<td>sortis</td>
</tr>
<tr>
<td>fur:r</td>
<td>furris</td>
</tr>
<tr>
<td>mumur</td>
<td>mumuris</td>
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<td>augur</td>
<td>auguris</td>
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<tr>
<td>arbor</td>
<td>arboris</td>
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<tr>
<td>pugil</td>
<td>pugilis</td>
</tr>
<tr>
<td>sal</td>
<td>salis</td>
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<tr>
<td>adeps</td>
<td>adipis</td>
</tr>
<tr>
<td>apeks</td>
<td>apikis</td>
</tr>
</tbody>
</table>

4 Latin

Provide a complete account of the following phonological alternations in Latin, including underlying forms for noun stems.
The following six 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.

What other phonological rule or rules are needed to account for the following data?

Die:s die:i: ‘day’
li:ber li:beri: ‘free’
miser miseri: ‘wretched’
ager a:gi: ‘field’
sinister sini:stri: ‘left’
liber li:bi: ‘book’

5 Turkish
Provide a phonological analysis of the following data from Turkish. Note that long vowels like [a:] are phonetically distinct from identical vowel clusters like [aa].
Doing an analysis
Propose rules to account for the following alternations. It will prove useful to think about Kera vowels in terms of high versus nonhigh vowels. Also, in this language it would be convenient to assume that [h] and [ʔ] are specified as [+low]. Pay attention to all verb forms like *bilan* ‘want me,’ *balnai* ‘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.

<table>
<thead>
<tr>
<th>Verb Root</th>
<th>Present Form</th>
<th>Past Form</th>
<th>Imperative Form</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>inek</em></td>
<td><em>inei</em></td>
<td><em>inee</em></td>
<td><em>inek</em></td>
</tr>
<tr>
<td><em>mantik</em></td>
<td><em>mantii</em></td>
<td><em>mantia</em></td>
<td><em>mantik</em></td>
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<tr>
<td><em>ajak</em></td>
<td><em>ajai</em></td>
<td><em>aja</em></td>
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</tr>
<tr>
<td><em>t'abuk</em></td>
<td><em>t'abuu</em></td>
<td><em>t'abua</em></td>
<td><em>t'abuk</em></td>
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<td><em>dakii</em></td>
<td><em>dakie</em></td>
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<td><em>merak</em></td>
<td><em>merak'i</em></td>
<td><em>merak'a</em></td>
<td><em>merak</em></td>
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<tr>
<td><em>tebrik</em></td>
<td><em>tebr'i ki</em></td>
<td><em>tebr'i ke</em></td>
<td><em>tebrik</em></td>
</tr>
<tr>
<td><em>hukuk</em></td>
<td><em>huk'u ku</em></td>
<td><em>huk'u ka</em></td>
<td><em>hukuk</em></td>
</tr>
</tbody>
</table>

---

**6 Kera**

'haman' ‘eat me’

'hamam' ‘eat you (masc)’

'himi' ‘eat you (fem)’

'himu' ‘eat him’

'hama' ‘eat her’

'hamaŋ' ‘eat you (pl)’

'kolon' ‘change me’

'kolom' ‘change you (masc)’

'kuli' ‘change you (fem)’

'kulu' ‘change him’

'kola' ‘change her’

'koloŋ' ‘change you (pl)’

'ciriri' ‘your (masc) head’

'cirir' ‘your (fem) head’

'curu' ‘his head’

'cir'i' ‘her head’

'ciririŋ' ‘your (pl) head’

'bilan' ‘want me’

'bilam' ‘want you (masc)’

'bili' ‘want you (fem)’

'bilu' ‘want him’

'bila' ‘want her’

'biluŋ' ‘want you (pl)’
Account for the alternations in the following verbs. The different forms relate to whether the action is in the past or future, and which element in the sentence is emphasized (subject, object, instrument). Roots underlyingly have the shape CVC(C)VC, and certain 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] (ʔum-bebhat — behat) or doubling the middle consonant (ʔum-buŋŋet — buŋ). The contrastive identification imperfective form conditions lengthening of the consonant in the middle of the stem, when the first vowel is not [e] (memajju — baju). These changes are 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 and affix.

Understanding the status of [s] and [h] in this language is important in solving this problem. It is also important to consider exactly what underlying nasal consonant is present in these various prefixes and infixes — there is evidence in the data which shows that the underlying nature of the nasal explains certain observed differences in phonological behavior.

<table>
<thead>
<tr>
<th>Subject focus</th>
<th>Direct object</th>
<th>Instrumental focus</th>
</tr>
</thead>
<tbody>
<tr>
<td>future</td>
<td>past</td>
<td>past</td>
</tr>
<tr>
<td>ʔumduntuk</td>
<td>dinuntuk</td>
<td>ʔinduntuk</td>
</tr>
<tr>
<td>ʔumbajju?</td>
<td>binaju?</td>
<td>ʔimbajju?</td>
</tr>
</tbody>
</table>

7 Keley-i

Account for the alternations in the following verbs. The different forms relate to whether the action is in the past or future, and which element in the sentence is emphasized (subject, object, instrument). Roots underlyingly have the shape CVC(C)VC, and certain 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] (ʔum-bebhat ← behat) or doubling the middle consonant (ʔum-buŋŋet ← buŋ). The contrastive identification imperfective form conditions lengthening of the consonant in the middle of the stem, when the first vowel is not [e] (memajju? ← baju?). These changes are 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 and affix.

Understanding the status of [s] and [h] in this language is important in solving this problem. It is also important to consider exactly what underlying nasal consonant is present in these various prefixes and infixes — there is evidence in the data which shows that the underlying nature of the nasal explains certain observed differences in phonological behavior.
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.

| ?umdillag | dinilag | ?indilag | 'light lamp' |
| ?ungubbat | ginubat | ?jingubat | 'fight' |
| ?umhullat | hinulat | ?inhulat | 'cover' |
| ?umbuŋyet | binuŋyet | ?imbuŋyet | 'scold' |
| ?umgalgal | ginalgal | ?ingalgal | 'chew' |
| ?umʔagtuʔ | ?inagtuʔ | ?inʔagtuʔ | 'carry on head' |
| ?umʔehney | ?inehney | ?inʔehney | 'stand' |
| ?umbebhat | binbebhat | ?imbebhat | 'cut rattan' |
| ?umdedek | dindedek | ?indedek | 'accuse' |
| ?umtuggun | sinuggun | ?intuggun | 'advise' |
| ?umtepeten | simpeten | ?intepeten | 'measure' |
| ?umpepetut | pintut | ?impetut | 'dam' |
| ?umhewpuy | himpuŋ | ?inhepuŋ | 'break a stick' |
| ?umtektuk | siŋkuk | ?intekuk | 'shout' |
| ?umkeket | kimbet | ?iŋkebet | 'scratch' |
| ?umbeddad | bindad | ?imbedad | 'untie' |
| ?umdedgeh | diŋgeh | ?indegeh | 'sick' |

**Instrumental Contrastive**

| past focus | id. imperfective | id. perfective |
| ?induntuk | menuntuk | nenuntuk | 'punch' |
| ?imbajuʔ | memajuʔ | nemajuʔ | 'pound rice' |
| ?indilag | menilag | nenilag | 'light lamp' |
| ?jingubat | meŋgubat | neŋgubat | 'fight' |
| ?inhulat | menullat | nenullat | 'cover' |
| ?intanem | menannem | nenannem | 'plant' |
| ?impedug | memdug | nemdug | 'chase' |
| ?imbedad | memdad | nemdad | 'untie' |
| ?iŋkebet | menbet | neŋbet | 'scratch' |
| ?imbedad | memdad | nemdad | 'dig' |
| ?intepe | mempen | nempen | 'kill a pig' |
| ?intebaʔ | membaʔ | nembaʔ | 'shout' |
| ?intekuk | menkuk | neŋkuk | 'sick' |
| ?indegeh | mengeh | neŋgeh | 'possess' |
| ?inhepaw | mempaw | nempaw | 'sting' |
| ?inteled | menled | nenled | 'accuse' |
| ?indeʔek | menŋek | nenŋek | 'carry on back' |
| ?inʔebaʔ | meŋbaʔ | neŋbaʔ | 'drink' |
| ?inʔinum | menjum | neŋjum | 'carry on head' |
| ?inʔagtuʔ | meŋgatuʔ | neŋgatuʔ | 'get' |
| ?inʔalaʔ | meŋjalaʔ | neŋjalaʔ | 'get' |

The following past focus clausal forms involve a different prefix, using some of the roots found above. A number of roots require reduplication of the first root syllable.

| ?induntuk | 'punch' | nampepedug | 'chase' |
| ?imbajuʔ | 'pound rice' | nambekeʔ | 'dig' |
| ?indilag | 'light lamp' | nambebeʔ | 'accuse' |
In some (but not all) of the examples below, morpheme boundaries have been introduced to assist in the analysis. Pronouns are assigned to a grammatical class depending on the noun which they refer to, conventionally given a number (1–20). Tone may be disregarded (however, it is predictable in the infinitive). It is important to pay attention to interaction between processes in this problem.

<table>
<thead>
<tr>
<th>Word</th>
<th>Meaning</th>
<th>Word</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>ogo-táangá</td>
<td>'to begin'</td>
<td>oko-gésa</td>
<td>'to harvest'</td>
</tr>
<tr>
<td>ogo-rága</td>
<td>'to witch'</td>
<td>oko-réma</td>
<td>'to plow'</td>
</tr>
<tr>
<td>ogo-htaóra</td>
<td>'to thresh'</td>
<td>ugu-súraangá</td>
<td>'to sing praise'</td>
</tr>
<tr>
<td>ugu-tuíúhá</td>
<td>'to be blunt'</td>
<td>uku-glíngá</td>
<td>'to shave'</td>
</tr>
<tr>
<td>ogo-kó-bára</td>
<td>'to count you (sg)'</td>
<td>uku-gú-súraangá</td>
<td>'to praise you (sg)'</td>
</tr>
<tr>
<td>ogo-mó-bára</td>
<td>'to count him'</td>
<td>uku-mú-súraangá</td>
<td>'to praise him'</td>
</tr>
<tr>
<td>ogo-tó-bára</td>
<td>'to count us'</td>
<td>ugu-tú-súraangá</td>
<td>'to praise us'</td>
</tr>
<tr>
<td>ogo-gé-bára</td>
<td>'to count them (4)'</td>
<td>uku-gí-súraangá</td>
<td>'to praise it (4)'</td>
</tr>
<tr>
<td>ogo-ré-bára</td>
<td>'to count it (5)'</td>
<td>uku-ri-súraangá</td>
<td>'to praise it (5)'</td>
</tr>
<tr>
<td>uku-bí-bára</td>
<td>'to count it (8)'</td>
<td>uku-bí-súraangá</td>
<td>'to praise it (8)'</td>
</tr>
<tr>
<td>ugu-tí-bára</td>
<td>'to count it (10)'</td>
<td>ugu-tí-súraangá</td>
<td>'to praise it (10)'</td>
</tr>
<tr>
<td>ogo-mó-go-gépséra</td>
<td>'to harvest it (3) for him'</td>
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<td></td>
</tr>
<tr>
<td>uku-mú-gú-súlkja</td>
<td>'to make him close it (3)'</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ogo-bá-súraangá</td>
<td>'to praise them'</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ogo-mó-bá-súraangéra</td>
<td>'to praise them for him'</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ogo-bá-mú-súraangéra</td>
<td>'to praise him for them'</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**To V for To make to V**

<table>
<thead>
<tr>
<th>Word</th>
<th>Meaning</th>
<th>Word</th>
<th>Meaning</th>
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</thead>
<tbody>
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<td>ogosáánsá</td>
<td>ogosáánsjá</td>
<td>ogosáánsérá</td>
<td>ogosáánsérá</td>
</tr>
</tbody>
</table>

---

**8 Kuría**

In some (but not all) of the examples below, morpheme boundaries have been introduced to assist in the analysis. Pronouns are assigned to a grammatical class depending on the noun which they refer to, conventionally given a number (1–20). Tone may be disregarded (however, it is predictable in the infinitive). It is important to pay attention to interaction between processes in this problem.

<table>
<thead>
<tr>
<th>Word</th>
<th>Meaning</th>
<th>Word</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>nanʔeʔebaʔ</td>
<td>'carry on back'</td>
<td>nanʔiʔinum</td>
<td>'drink'</td>
</tr>
<tr>
<td>nantanem</td>
<td>'plant'</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Word</th>
<th>Meaning</th>
</tr>
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<tbody>
<tr>
<td>nanʔeʔebaʔ</td>
<td>'carry on back'</td>
</tr>
<tr>
<td>nantanem</td>
<td>'plant'</td>
</tr>
<tr>
<td>nanʔiʔinum</td>
<td>'drink'</td>
</tr>
</tbody>
</table>

---
9 Lardil

Account for the phonological alternations seen in the data below.

<table>
<thead>
<tr>
<th>Bare N</th>
<th>Accusative</th>
<th>Nonfuture</th>
<th>Future</th>
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<tbody>
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<td>kentapalur</td>
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<td>kentinar</td>
<td>kentinur</td>
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</table>
10 Sakha (Yakut)

Give a phonological analysis of the following case-marking paradigms of nouns in Sakha.

<table>
<thead>
<tr>
<th>Noun</th>
<th>Plural</th>
<th>Associative</th>
</tr>
</thead>
<tbody>
<tr>
<td>aya</td>
<td>ayalar</td>
<td>ayalin</td>
</tr>
<tr>
<td>paarta</td>
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<tr>
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<td>Comparative</td>
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<tr>
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<tr>
<td>Noun</td>
<td>Dative</td>
<td>Accusative</td>
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<tr>
<td>-------</td>
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<td>ati</td>
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<td>baligi</td>
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<tr>
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<td>iskaapka</td>
<td>iskaabi</td>
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<tr>
<td>ouys</td>
<td>ouyska</td>
<td>ouyu</td>
</tr>
<tr>
<td>kus</td>
<td>kuska</td>
<td>kuhu</td>
</tr>
</tbody>
</table>

Nouns and their cases in a hypothetical language.
Give a phonological analysis of the following data. Assume that all surface occurrences of k' and g' 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. Nouns in declension II depalatalize a consonant before the locative suffix, and nouns in declension III depalatalize in the genitive. The variation in the genitive and locative singular suffix in declension I (-i or -a versus -u) is lexically governed: do not write rules which select between these suffixes. Concentrate on establishing the correct underlying representations for the noun stem.

<table>
<thead>
<tr>
<th>Noun</th>
<th>Our N</th>
<th>Noun</th>
<th>Our N</th>
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<tbody>
<tr>
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<td>ije</td>
<td>ijebit</td>
</tr>
<tr>
<td>uol</td>
<td>ulbut</td>
<td>kotor</td>
<td>kotornil</td>
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<tr>
<td>kilas</td>
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<td>iskaap</td>
<td>iskaappit</td>
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<td>kuroappit</td>
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<td>tiispit</td>
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<td>ohoappit</td>
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<td>tynnykpyt</td>
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<td>ammit</td>
<td>kapitan</td>
<td>kapitammot</td>
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<td>tiij</td>
<td>tiimm</td>
<td>onro</td>
<td>oorommot</td>
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<tr>
<td>kyn</td>
<td>kymmyt</td>
<td>'father'</td>
<td>'mother'</td>
</tr>
<tr>
<td>'father'</td>
<td>'son'</td>
<td>'classroom'</td>
<td>'bird'</td>
</tr>
<tr>
<td>'classroom'</td>
<td>'town'</td>
<td>'stove'</td>
<td>'cabinet'</td>
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<td>'door'</td>
<td>'squirrel'</td>
<td>'tooth'</td>
</tr>
<tr>
<td>'squirrel'</td>
<td>'day'</td>
<td></td>
<td>'window'</td>
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### Declension I

<table>
<thead>
<tr>
<th>Nom sg</th>
<th>Gen sg</th>
<th>Loc sg</th>
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<tbody>
<tr>
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<td>plas'ki</td>
</tr>
<tr>
<td>'skorux'</td>
<td>skoru'xa</td>
<td>skoru'si</td>
</tr>
<tr>
<td>'g'riux'</td>
<td>g'rix</td>
<td>g'ri'i</td>
</tr>
<tr>
<td>'pastu'x'</td>
<td>pastu'xa</td>
<td>pastu'si</td>
</tr>
<tr>
<td>'m'nh'lua</td>
<td>m'nh'lua</td>
<td>m'nh'usi</td>
</tr>
<tr>
<td>'plu'ya</td>
<td>'plu'ya</td>
<td>'plu'zi</td>
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<td>'saka'</td>
<td>'stoz'i</td>
</tr>
<tr>
<td>'sak'</td>
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<td>'stoz'y'</td>
</tr>
</tbody>
</table>

11 Sadzhava Ukrainian

Give a phonological analysis of the following data. Assume that all surface occurrences of k' and g' 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. Nouns in declension II depalatalize a consonant before the locative suffix, and nouns in declension III depalatalize in the genitive. The variation in the genitive and locative singular suffix in declension I (-i or -a versus -u) is lexically governed: do not write rules which select between these suffixes. Concentrate on establishing the correct underlying representations for the noun stem.
<table>
<thead>
<tr>
<th>Declension II</th>
<th>Declension III</th>
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<tbody>
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<td><strong>Nom sg</strong></td>
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<td>d'mi le</td>
</tr>
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<td>kri'il</td>
<td>krb'i le</td>
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<td>u t'elata</td>
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<td>'graeb'nan</td>
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<td>'olan'</td>
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<td>yat'mænæ</td>
</tr>
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<td>'yas'in</td>
<td>'yasænæ</td>
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<td>'plota</td>
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<td>'smroda</td>
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<td>fos'ta</td>
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<td>'mosta</td>
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<td>'drota</td>
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<td>'maed'u</td>
</tr>
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<td>'sno'pa</td>
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<td>yra'ba</td>
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<tr>
<td>'porf'i</td>
<td>po'roya</td>
</tr>
<tr>
<td>bo 'lek</td>
<td>bol'a ka</td>
</tr>
<tr>
<td>'vorlhy</td>
<td>'voroya</td>
</tr>
<tr>
<td>'konok</td>
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<td>'potik</td>
<td>po'toka</td>
</tr>
<tr>
<td>'t'ik</td>
<td>'toka</td>
</tr>
<tr>
<td>'k'li</td>
<td>ko'la</td>
</tr>
</tbody>
</table>

- 'blacksmith'
- 'bumblebee'
- 'rabbit'
- 'teacher'
- 'comb'
- 'deer'
- 'barley'
- 'ash tree'
- 'son-in-law'

- 'fat'
- 'death'
- 'news'
- 'salt'
- 'epidemic'
- 'snowstorm'
- 'tablecloth'
- 'bone'
Koromfe has two kinds of vowels, \([-\text{ATR}] \ \iota \ \varepsilon \ \o \ \a\) and \([+\text{ATR}] \ \iota \ \varepsilon \ \o \ \a\). Provide an analysis of the alternations in the following data, which involve singular and plural forms of nouns and different tense-infections for verbs:

<table>
<thead>
<tr>
<th>Singular</th>
<th>Plural</th>
<th>Neutral Past Progressive</th>
</tr>
</thead>
<tbody>
<tr>
<td>gɪba:</td>
<td>gba</td>
<td>&quot;hatchet&quot;</td>
</tr>
<tr>
<td>hubre</td>
<td>huba</td>
<td>&quot;ditch&quot;</td>
</tr>
<tr>
<td>nebɛ</td>
<td>neba</td>
<td>&quot;pea&quot;</td>
</tr>
<tr>
<td>dĩgre</td>
<td>dĩga</td>
<td>&quot;bush type&quot;</td>
</tr>
<tr>
<td>zongre</td>
<td>zonga</td>
<td>&quot;wing&quot;</td>
</tr>
<tr>
<td>lȃngle</td>
<td>lȃnga</td>
<td>&quot;shoe&quot;</td>
</tr>
<tr>
<td>hullre</td>
<td>hulla</td>
<td>&quot;gutter&quot;</td>
</tr>
<tr>
<td>sekɛ</td>
<td>seka</td>
<td>&quot;half&quot;</td>
</tr>
<tr>
<td>tefrɛ</td>
<td>tɛfa</td>
<td>&quot;cotton fiber&quot;</td>
</tr>
<tr>
<td>dabɛɛɛ</td>
<td>dabɛja</td>
<td>&quot;camp&quot;</td>
</tr>
<tr>
<td>dɔɔɛɛ</td>
<td>dɔɔja</td>
<td>&quot;long&quot;</td>
</tr>
<tr>
<td>gĩgaɛɛ</td>
<td>gĩgaaja</td>
<td>&quot;vulture&quot;</td>
</tr>
<tr>
<td>pupaɛɛ</td>
<td>pupaaja</td>
<td>&quot;grass type&quot;</td>
</tr>
<tr>
<td>koire</td>
<td>koja</td>
<td>&quot;bracelet&quot;</td>
</tr>
<tr>
<td>dɔɔmɛɛ</td>
<td>dɔɔma</td>
<td>&quot;lion&quot;</td>
</tr>
<tr>
<td>hulomde</td>
<td>huloma</td>
<td>&quot;marrow&quot;</td>
</tr>
<tr>
<td>temɛɛ</td>
<td>tuma</td>
<td>&quot;beard&quot;</td>
</tr>
<tr>
<td>logomde</td>
<td>logomla</td>
<td>&quot;camel&quot;</td>
</tr>
<tr>
<td>bindɛ</td>
<td>bina</td>
<td>&quot;heart&quot;</td>
</tr>
<tr>
<td>hũndɛ</td>
<td>hũna</td>
<td>&quot;hoe&quot;</td>
</tr>
<tr>
<td>honde</td>
<td>hɔna</td>
<td>&quot;bean&quot;</td>
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<td>gɛɛnde</td>
<td>gɛɛna</td>
<td>&quot;pebble&quot;</td>
</tr>
<tr>
<td>zãɛɛde</td>
<td>zãɛɛna</td>
<td>&quot;upper arm&quot;</td>
</tr>
<tr>
<td>bũlɛɛ</td>
<td>bũla</td>
<td>&quot;back&quot;</td>
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<tr>
<td>jɪlɛ</td>
<td>jɪla</td>
<td>&quot;horn&quot;</td>
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<tr>
<td>sɛlɛɛ</td>
<td>sɛlɛ</td>
<td>&quot;space&quot;</td>
</tr>
<tr>
<td>pala</td>
<td>pala</td>
<td>&quot;stretcher&quot;</td>
</tr>
<tr>
<td>dɛɛŋgele</td>
<td>dɛɛŋgelɛ</td>
<td>&quot;open area&quot;</td>
</tr>
<tr>
<td>dɛɛmbɛɛle</td>
<td>dɛɛmbɛɛlɛ</td>
<td>&quot;piece&quot;</td>
</tr>
<tr>
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<td>dãɛɛja</td>
<td>&quot;wood&quot;</td>
</tr>
<tr>
<td>hũmɛɛ</td>
<td>hũja</td>
<td>&quot;caterpillar&quot;</td>
</tr>
<tr>
<td>kɔɛɛɛɛ</td>
<td>kɔɛɛja</td>
<td>&quot;squirrel&quot;</td>
</tr>
<tr>
<td>kãɛɛɛɛ</td>
<td>kãɛɛja</td>
<td>&quot;old&quot;</td>
</tr>
<tr>
<td>sãɛɛɛɛ</td>
<td>sãɛɛja</td>
<td>&quot;period&quot;</td>
</tr>
<tr>
<td>bɛɛtɛɛ</td>
<td>bɛɛta</td>
<td>&quot;male animal&quot;</td>
</tr>
<tr>
<td>dãɛɛɛɛ</td>
<td>dãɛɛra</td>
<td>&quot;chest&quot;</td>
</tr>
<tr>
<td>getɛɛ</td>
<td>getɛɛ</td>
<td>&quot;forked stick&quot;</td>
</tr>
<tr>
<td>gořɛɛ</td>
<td>gořɛɛ</td>
<td>&quot;stream&quot;</td>
</tr>
<tr>
<td>brɛɛ</td>
<td>brɛɛ</td>
<td>&quot;frog&quot;</td>
</tr>
<tr>
<td>dɔɔɛɛ</td>
<td>dɔɔra</td>
<td>&quot;cloud&quot;</td>
</tr>
</tbody>
</table>

**Neutral**

| ta | tɛɛ | taraa | "shoot" |
| gɔ | gɔɛɛ | gɔxɛɛa | "go back" |
| ku | kɔɛɛ | kɔraa | "kill" |
Further reading
One of the main goals of many phonologists is to explain why certain phonological patterns are found in numerous languages, while other patterns are found in few or no languages. This chapter looks at phonological typology – the study of common versus uncommon phonological rules.

**KEY TERMS**
typology
crosslinguistic comparison
markedness
functional explanation
A widely invoked criterion in deciding between analyses of a language is whether the rules of one analysis are more natural, usually judged in terms of whether the rules occur frequently 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 such survey 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 reason for these patterns.

7.1 Inventories

A comparative, typological approach is often employed 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 or rules have equal status in phonological systems. For example, many languages have the stop consonants [p t k], a system that is 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 than [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 [ɮ]. Very many languages have the vowels [i e a o u]; not many have the vowels [ɨ œ ʊɪ].

Related to frequency of segment types across languages is the concept of implicational relation. An example of an implicational relation is that holding between oral and nasal vowels. Many languages have only oral vowels (Spanish, German), and many languages have both oral and nasal vowels (French, Portuguese), but no language has 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 has only voiced obstruents.

The method of comparing inventories. Three methodological issues need to be borne in mind when conducting such typological studies. First, determining 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 may result in error. The consonants spelled <p t k> may in fact be ejective [pʼ tʼ kʼ], 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 nonejective 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 <ptk> 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,” unless 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; least common are pharyngeal. 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 pharyngealization of consonants. Among consonants with multiple closures, labiovelars like [kp] are the most common; clicks, though rare, seem to be more common than linguolabials.

In terms of manners of consonant articulation, stops are found in all languages. Most languages have at least one fricative (but many Australian languages have no fricatives), and the most common fricative is ʃ, followed by f and ?, then x, then θ and other fricatives. The most common affricates are the alveopalatal, then other coronal affricates; p’ and k’ are noticeably less frequent. In terms of laryngeal properties of consonants, all languages have voiceless consonants (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 j]. Modal voicing is the unmarked case for liquids, nasals, and glides, with distinctive laryngealization 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 than 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 [y] and not [ø], but very few have [ø] and not [y]. Full exploitation of the possibilities for low back and round vowels [æ ø a ø] is quite rare, but it is not hard to find languages with [i y i 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.

7.2 Segmental processes

Recurrent patterns are also found in rules themselves. We begin our typological survey of processes with segmental processes and proceed 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 differences between segmental, i.e. featural, representations and syllabic or rhythmic representations – further questions regarding representations are taken up in chapter 9.

7.2.1 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 archetypical 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 suffixes alternate according to the frontness of the preceding vowel. The genitive suffix accordingly varies between -in and -ɨn, as does the plural suffix lar ~ ler.

<table>
<thead>
<tr>
<th>(1)</th>
<th>Nom sg</th>
<th>Gen sg</th>
<th>Nom pl</th>
<th>Gen pl</th>
</tr>
</thead>
<tbody>
<tr>
<td>ip</td>
<td>ip-in</td>
<td>ip-ler</td>
<td>ip-ler-in</td>
<td>‘rope’</td>
</tr>
<tr>
<td>tʃɨkiʃ</td>
<td>tʃɨkiʃ-in</td>
<td>tʃɨkiʃ-lar</td>
<td>tʃɨkiʃ-lar-in</td>
<td>‘exit’</td>
</tr>
<tr>
<td>kiz</td>
<td>kiz-in</td>
<td>kiz-lar</td>
<td>kiz-lar-in</td>
<td>‘girl’</td>
</tr>
</tbody>
</table>
This process can be stated formally as (2).

(2) \( V \rightarrow [\alpha_{\text{back}}] / V \ C_0 - \)

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
--- | --- | --- | ---
jyz | jyz-yn | jyz-ler | jyz-ler-in ‘face’
pul | pul-un | pul-lar | pul-lar-in ‘stamp’
ok | ok-un | ok-lar | ok-lar-in ‘arrow’
son | son-un | son-lar | son-lar-in ‘end’
køj | køj-yn | køj-ler | køj-ler-in ‘village’

The genitive suffix which has a high vowel becomes rounded when the preceding vowel is round, but the plural suffix which has a nonhigh vowel does not assimilate in roundness. Thus the data in (3) can be accounted for by the following rule.

(4) \( V \rightarrow [\alpha_{\text{round}}] / V \ C_0 - \)

A problem that arises in many vowel harmony systems is that it is difficult if not impossible to be certain what the underlying vowel of the suffix is. For the plural suffix, we can surmise that the underlying vowel is nonround, since it is never phonetically round, so the most probable hypotheses are /a/ or /e/. For the genitive suffix, any of /i/, /y/, /u/ would be plausible, since from any of these vowels, the correct output would 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 (crosslinguistically frequent) segment should be selected over a more marked segment. By that reasoning, you might narrow the choice to /i/, /u/ since /i/, /y/, /u/ would be less marked than /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 than /u/: however, that conclusion regarding markedness is not certain. The validity of invoking segmental markedness for choosing 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 in Turkish are not specified at all for backness or roundness, and thus could be represented with the symbol /I/, which is not an actual and pronounceable vowel, but represents a so-called archiphoneme 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 nonhigh vowels undergo the assimilation, and only nonhigh vowels trigger the process.

(5)  

<table>
<thead>
<tr>
<th></th>
<th>Nominative</th>
<th>Instrumental</th>
<th>Accusative</th>
</tr>
</thead>
<tbody>
<tr>
<td>de:l</td>
<td>de:l:e:r</td>
<td>de:l:i:g</td>
<td>‘coat’</td>
</tr>
<tr>
<td>gal</td>
<td>gal:a:r</td>
<td>gal:i:g</td>
<td>‘fire’</td>
</tr>
<tr>
<td>dy:</td>
<td>dy:-ge:r</td>
<td>dy:-g</td>
<td>‘younger brother’</td>
</tr>
<tr>
<td>nøxør</td>
<td>nøxør:-ø:r</td>
<td>nøxør:i:g</td>
<td>‘comrade’</td>
</tr>
<tr>
<td>doro:</td>
<td>doro:-go:r</td>
<td>doro:-g</td>
<td>‘stirrup’</td>
</tr>
</tbody>
</table>

This rule can be formulated as in (6).

(6)  

\[
V \rightarrow [\text{around}] / V \quad C_{0-} \\
[- \text{high}] \quad [- \text{high}] \quad [\text{around}]
\]

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 nonhigh vowels (cf.: aγa-liin ‘father (associative),’ sep-tiin ‘tool (associative)’ vs. oγo-luun ‘child (associative),’ børø-lyyn ‘wolf (associative),’ tynnyktyyn ‘window (associative)’), but nonhigh vowels only assimilate in roundness to a preceding nonhigh vowel (cf. aγa-lar ‘fathers,’ sep-ter ‘tools,’ tynnyk-ter ‘windows,’ kus-tar ‘ducks’ vs. oγo-lor ‘children,’ børø-lør ‘wolves’). As seen in chapter 6, in Yawelmani, vowels assimilate rounding from a preceding vowel of the same height (thus, high vowels assimilate to high vowels, low vowels assimilate to low vowels). As seen in (7), Kirghiz vowels generally assimilate in roundness to any preceding vowel except that a nonhigh vowel does not assimilate to a back high round vowel (though it will assimilate rounding from a front high round vowel).

(7)  

<table>
<thead>
<tr>
<th>Accusative</th>
<th>Dative</th>
</tr>
</thead>
<tbody>
<tr>
<td>taj-ti</td>
<td>taj-ka</td>
</tr>
<tr>
<td>iŋ-ti</td>
<td>iŋ-ke</td>
</tr>
<tr>
<td>utŋ-tu</td>
<td>utŋ-ka</td>
</tr>
</tbody>
</table>
This survey raises the question whether you might find a language where roundness harmony only takes place between vowels of different heights rather than the same height, as we have seen. Although 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 genetically or areally related (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 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) omo-ńto ‘person’ omo-sáátá ‘male’
omo-té ‘tree’ omo-góóndo ‘plowed field’
umu-rísja ‘boy’ umu-múra ‘young man’
eme-té ‘trees’ imi-sí ‘sugar canes’
egé-sáka ‘stream’ ege-té ‘chair’
egéé-ńto ‘thing’ igi-túúmbe ‘stool’
iki-rúúngúuri ‘soft porridge’ iki-múún ‘deer’
ogo-gábo ‘huge basket’ ogo-tábo ‘huge book’
ogo-sééndáno ‘huge needle’ ogo-gína ‘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, e, o, ə, 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 show that the prefixes must underlyingly contain mid vowels; there are also prefixes which contain invariantly [+high] vowels.

(9) iri-tóóke ‘banana’ iri-kééndó ‘date fruit’
iri-húíndi ‘corn cob’ iri-tóó ‘buttock’
ibi-góóndo ‘small fields’ ibi-gááte ‘small breads’
ibi-gúrúbe ‘small pigs’ ibi-té ‘chairs’
it’i-séé̂ ‘dog’ it’i-ŋáámi ‘cat’
it’i-ngóobé ‘cow’ it’i-ngúrúbe ‘pig’

Thus the alternations in (8) can be described with the rule (10).
Another variety of vowel-height harmony is complete height harmony, an example of which is found in Matuumbi. This language distinguishes four phonological vowel heights, exemplified by the vowels $a$, $ε$, $ɪ$ and $i$. The vowels of the passive suffix -ilw- and the causative suffix -ij- assimilate completely to the height of the preceding nonlow vowel [$ε$ $ɪ$ $i$].

This process involves the complete assimilation of suffix vowels to the values of [high] and [tense] (or [ATR]) from the preceding nonlow 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).

\[
\begin{array}{c}
V \\
[+ \text{low}] \quad \rightarrow [+ \text{high}] \big/ \mathcal{C}_0 \quad V \\
[+ \text{tense}] \quad \rightarrow \quad + \text{low} \quad \big/ \mathcal{C}_0 - \big/ \ \text{βtense} \quad \big/ \ \text{αhigh} \quad \big/ \ \text{βtense} \\
\end{array}
\]

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 the word for ‘eat’ and [−ATR] before the [−ATR] vowel of ‘be called’; (13b) shows this same harmony affecting other tense–aspect prefixes.

(13) a. ‘eat’ ‘be called’
   1sg mi-di mi-di
   2sg wu-di wo-di
   3sg o-di o-di
   1pl je-di je-di
b. vowel nasalization is also a common assimilatory process affecting vowels, and can be seen in the data of (14) from Gã. These data illustrate nasalization affecting the plural suffix, which is underlyingly /i/ and assimilates nasality from the immediately preceding vowel.

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 /e/ (but not /el/) becomes [a] before [a], [ɔ] before [ɔ], [ɛ] before [ɛ], [e] before [e] and [i], and [o] before [o] and [u].

This process involves assimilation of all features from the following vowel, except the feature [high].

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 | 1sg pres | 1sg past | Imperative |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>/tum/</td>
<td>tum-atun</td>
<td>tum-tan</td>
<td>tum</td>
</tr>
<tr>
<td>/agul/</td>
<td>agul-atun</td>
<td>agul-tan</td>
<td>agul</td>
</tr>
<tr>
<td>/dakap/</td>
<td>dakap-atun</td>
<td>dakap-tan</td>
<td>dakap</td>
</tr>
<tr>
<td>/katk/</td>
<td>katk-atun</td>
<td>katk-tan</td>
<td>katk</td>
</tr>
<tr>
<td>/melg/</td>
<td>melg-atun</td>
<td>meleg-tan</td>
<td>meleg</td>
</tr>
<tr>
<td>/kink/</td>
<td>kink-atun</td>
<td>kink-tan</td>
<td>kink</td>
</tr>
</tbody>
</table>

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-Γe:ml’ema | ‘makes someone dizzy’ |
| sno-bo:stgi | ‘causes something to turn black’ |
| sni-nklílk’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 context 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,’ p’ā-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 the following consonant. An example of this process comes from Matuumbi, seen in (19), where the plural prefix $ɲ$ takes on the place of assimilation of the following consonant.

(19) | Singular | Plural |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>lwímo</td>
<td>nímo</td>
</tr>
<tr>
<td>lwaámbo</td>
<td>naámbo</td>
</tr>
<tr>
<td>lweémbé</td>
<td>neémbe</td>
</tr>
<tr>
<td>lugolóká</td>
<td>ngolóká</td>
</tr>
<tr>
<td>lubáu</td>
<td>mbáu</td>
</tr>
<tr>
<td>ludíiŋgjá</td>
<td>ndíiŋgjá</td>
</tr>
<tr>
<td>lulaála</td>
<td>ndaála</td>
</tr>
<tr>
<td>lupalááí</td>
<td>mbalááí</td>
</tr>
<tr>
<td>lutéélá</td>
<td>ndeelá</td>
</tr>
<tr>
<td>lutʃwištʃwi</td>
<td>ndʃwištʃwi</td>
</tr>
</tbody>
</table>
Place assimilation of nasals in Matuumbi 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-bálaangite m-bálaangite ‘I counted’
    ni-dʰíngiile n-dʰíngiile ‘I entered’
    ni-góŋdʒite n-góŋdʒite ‘I slept’

b. mu-páalite m-páalite ‘you (pl) wanted’
    mu-téliike n-téliike ‘you (pl) cooked’
    mu-tʰáawiile n-tʰáawiile ‘you (pl) ground’
    mu-káatite n-káatite ‘you (pl) cut’

Sometimes, a language with place assimilation of nasals will restrict the process to a specific place of articulation. For instance, Chukchi assimilates n to a following consonant, but does not assimilate m. Thus the stem teŋ ‘good’ retains underlying n 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-əlʔ-ən ‘good’
    tam-wayarγ-ən ‘good life’
    tam-pera-k ‘to look good’
    tan-tʰottot ‘good pillow’
    tan-lmŋol ‘good story’
    tan-rʔarq ‘good breastband’
    nσ-mkə-kiŋ ‘often’
    γa-n-pera-w-len ‘decorated’

A common assimilation affecting consonants after nasals is postvocalic voicing, illustrated by Matuumbi in (22). The data in (22a) illustrate voicing of an underlyingly voiceless consonant at the beginning of a stem after the prefix ɲ. The data in (22b) show voicing of a consonant in a verb after the reduced form of the subject prefix ɲi. In these examples, the vowel /i/ in the prefix optionally deletes, and when it does, it voices an initial stop.

(22) a. Singular Plural
    lu-paláí m-baláí ‘bald head’
    lu-tʰwífítwi n-d’wífítwi ‘tomato plant’
    lu-téelá n-deelá ‘piece of wood’
    lu-ŋiligilo n-gitiligo ‘initiate’s place’
    lu-temá.á n-demá.á ‘chopped’
    lu-tʰapíštá n-d’apíštá ‘clean’

Not all preconsonantal nasals condition this voicing process in Matuumbi; only nasals which are nonsyllabic 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.
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 $a \sim o$, and undergo nasalization of that consonant before the past-tense suffix -$ninta$.

(23) a. **Infinitive** | **Past**
---|---
$an$-$a$ | $an$-$ninta$ | ‘hug’
$t'\text{at}im$-$\o$ | $t'\text{atim}$-$ninta$ | ‘trim’
$n\text{am}$-$\o$ | $n\text{am}$-$ninta$ | ‘overflow’
$t^{\text{th}}\text{am}$-$\o$ | $t^{\text{th}}\text{am}$-$ninta$ | ‘endure’

b. $ip$-$\o$ | $im$-$ninta$ | ‘wear’
$t\text{at}$-$\o$ | $tan$-$ninta$ | ‘close’
$p\text{uh}$-$\text{th}$-$\o$ | $pun$-$ninta$ | ‘adhere’
$t'\text{ot}^{\text{th}}$-$\o$ | $t'\text{on}$-$ninta$ | ‘follow’
$m\text{ak}$-$\o$ | $m\text{a}j$-$ninta$ | ‘eat’
$tak$-$\text{th}$-$\o$ | $tan$-$ninta$ | ‘polish’
$ik$-$\o$ | $i\text{ji}$-$ninta$ | ‘ripen’

Matuumbi presents the mirror-image process, of postnasal 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 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 $u$ from the prefix /$mu/$.

(24) a. $a$-$\text{ba}\text{nda}$ | ‘slaves’ | $m$-$\text{ma}\text{anda}$ | ‘slaves’
$a$-$\text{lallo}$ | ‘fools’ | $n$-$\text{nallo}$ | ‘fool’
$a$-$\text{gu}\text{ndumji}$ | ‘scarers’ | $\text{gj}u\text{ndumji}$ | ‘scarer’
$mi$-$\text{butuka}$ | ‘cars’ | $m$-$\text{mutuka}$ | ‘car’
$mi$-$\text{dala}\text{anzi}$ | ‘bitter oranges’ | $n$-$\text{alaanzi}$ | ‘bitter orange’
$mi$-$\text{lipu}$ | ‘trees (sp)’ | $n$-$\text{nipu}$ | ‘tree (sp)’
$mi$-$\text{guunda}$ | ‘fields’ | $\text{gj}u\text{un}\text{da}$ | ‘field’

b. $mu$-$\text{bu}\text{undike}$ | ‘you should store’
$mu$-$\text{laabuke}$ | ‘you should breakfast’
$mu$-$d'\text{ii}ngi$ | ‘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) kr̥nt\text{-}mas ḅind\text{-}mas 1pl indicative active
    kr̥nt\text{-}e ḅind\text{-}e 1sg indicative middle
    kr̥nt\text{-}tʰa ḅint\text{-}tʰa 2pl indicative active
    kr̥nt\text{-}te ḅint\text{-}e 3sg indicative middle
    kr̥nt\text{-}dʰve ḅind\text{-}dʰve 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 it 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’ çop-e çop-te ‘buy’
    tenk-e tenk-te ‘think’ behøv-e behøv-de ‘belong’
    lev-e lev-de ‘lived’ prøv-e prøv-de ‘try’
    bygg-e bygg-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’

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 illustrated below with the accusative case suffix /bəl/.

(27) asi:-ba ‘woman’ ɲami:-ba ‘female deer’
    palatka-ba ‘tent’ tolgo:ki:1-ba ‘sleds’
    ber-be ‘onion’ huna:t-pa ‘girl’
    det-pe ‘tundra’ mit-pe ‘1pl 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 nonassimilation when the following consonant is non-coronal, and those in (b) provide stems that begin with coronal consonants.

(28) \begin{tabular}{llll}
        & Indefinite & Definite & Indefinite & Definite \\
\hline
    a. & hawa & lhawa ‘air’ & ba:red & lba:red ‘cold’
         & ?adham & l?adham ‘black’ & madine & lmadine ‘city’
\end{tabular}
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) | Consonant | Vowel | Palatalization |
--- | --- | --- |
Sa:de | la:de | ‘custom’ |
whaf | lwhaf | ‘beast’ |
kalb | lkalb | ‘dog’ |
faij | laij | ‘shadow’ |
s’aff | l’s’aff | ‘row’ |
taxt | txatx | ‘bed’ |
nade | nnade | ‘dew’ |
difa:r | ddifa:r | ‘defense’ |
ja:ra | lja:ra | ‘despair’ |
xadd | lxadd | ‘cheek’ |
yada | lyada | ‘lunch’ |

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.

(30) | Consonant | Vowel | Palatalization |
--- | --- | --- |
vkus | um | ‘taste’ |
dolot | d | ‘hunger’ |
sto:l | stol | ‘table’ |
guba | guba | ‘lip’ |
mes:to | mest:o | ‘place’ |
glub-ok | glub-ok | ‘deep’ |
ton-ok | ton-ok | ‘thin’ |
vor | vor | ‘thief’ |
dom | dom | ‘house’ |
gorot | gorot | ‘town’ |

The alveopalatal fricatives s, z 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 [ts] before [u] and [tʰ] before [i].

(31)  

<table>
<thead>
<tr>
<th></th>
<th>Negative</th>
<th>Provisional</th>
<th>Infinitive</th>
<th>Volitional</th>
</tr>
</thead>
<tbody>
<tr>
<td>mat-ani</td>
<td>mat-ebā</td>
<td>matʰ-u</td>
<td>matʰ-itai</td>
<td>‘wait’</td>
</tr>
<tr>
<td>tat-ani</td>
<td>tat-ebā</td>
<td>tatʰ-u</td>
<td>tatʰ-itai</td>
<td>‘stand’</td>
</tr>
<tr>
<td>kat-ani</td>
<td>kat-ebā</td>
<td>katʰ-u</td>
<td>katʰ-itai</td>
<td>‘win’</td>
</tr>
</tbody>
</table>

Outside 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 involve either 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 vocoids.

(32)  

<table>
<thead>
<tr>
<th>N</th>
<th>with N</th>
<th>there are N’s</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>burro</td>
<td>kom burro</td>
<td>aj βurros</td>
<td>‘donkey’</td>
<td></td>
</tr>
<tr>
<td>débô</td>
<td>kon débô</td>
<td>aj ðèbôs</td>
<td>‘finger’</td>
<td></td>
</tr>
<tr>
<td>gato</td>
<td>kon gato</td>
<td>aj γatos</td>
<td>‘cat’</td>
<td></td>
</tr>
</tbody>
</table>

This can be seen as assimilation of the value [continuant] from a preceding vocoid.

An example of combined voicing and spirantization is found in Tibetan, where voiceless noncoronal stops become voiced spirants between vowels.

(33)  

<table>
<thead>
<tr>
<th>Past affirmative</th>
<th>Past negative</th>
</tr>
</thead>
<tbody>
<tr>
<td>tʰaa-βaree</td>
<td>ma-tʰaa-βaree</td>
</tr>
<tr>
<td>paa-βaree</td>
<td>ma-βaa-βaree</td>
</tr>
<tr>
<td>pii-βaree</td>
<td>ma-pii-βaree</td>
</tr>
<tr>
<td>kuu-βaree</td>
<td>ma-γuu-βaree</td>
</tr>
<tr>
<td>ka-βaree</td>
<td>ma-γa-βaree</td>
</tr>
<tr>
<td>qaa-βaree</td>
<td>ma-ʁaa-βaree</td>
</tr>
</tbody>
</table>

In some cases, the result of lenition is a glide, so in Axininca Campa, stem-initial /k, p/ become [j, w] after a vowel.

(34)  

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>jaarato</td>
<td>‘black bee’</td>
<td>no-jaaratoti</td>
<td>‘my black bee’</td>
<td></td>
</tr>
<tr>
<td>kanari</td>
<td>‘wild turkey’</td>
<td>no-kanariti</td>
<td>‘my wild turkey’</td>
<td></td>
</tr>
<tr>
<td>porita</td>
<td>‘small hen’</td>
<td>no-poritati</td>
<td>‘my small hen’</td>
<td></td>
</tr>
</tbody>
</table>

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 Matuumbi, sonorants become voiced stops after a nasal. The data in (35) illustrate this
phenomenon with the alternation in stem-initial consonant found between
the singular and plural.

(35)  lu-laála  ‘pepper plant’  n-daála  ‘pepper plants’
    lu-jimá  ‘pole’  n-díima  ‘poles’
    júkuta  ‘to be full’  n-díukutíá  ‘full’
    wá  ‘to die’  n-gwaáá  ‘dead’
    lindúla  ‘to guard’  n-dmðilá  ‘guarded’

Another context where hardening is common is when the consonant is
geominate. One example is found in Fula, where geominate spirants become
stops. In (36), plural forms have a medial geominate (this derives by an
assimilation to a following $ɗ$, so that $[tʃəbi]$ derives from $[tʃaw-ɗi]$ via the
intermediate stage $tʃawwi$).

(36)  Plural  Diminutive singular
    tʃəbi  tʃəwel  ‘stick’
    lebbi  lewel  ‘month’
    pobbi  powel  ‘hyena’
    næbbi  nèwel  ‘bean’
    leppi  lefel  ‘ribbon’
    koppi  kofel  ‘ear’
    tʃoppi  tʃofel  ‘chick’

Geominate hardening also occurs in Ganda. In the data of (37), the singular
form of nouns in this particular class is formed by geominating the initial
consonant: the underlying consonant is revealed in the plural.

(37)  Singular  Plural
    ggi  ma-gi  ‘egg’
    ddaala  ma-daala  ‘ladder’
    ddɔuba  ma-juba  ‘dove’
    ggʋaanga  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’
    ssaandɔa  ma-saandɔa  ‘dry plantain leaf’
    zzike  ma-zike  ‘chimpanzee’
    zziga  ma-ziga  ‘tear’
    vviivi  ma-viivi  ‘knee’

7.2.2 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, as 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     |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td></td>
</tr>
<tr>
<td>kusut</td>
<td>k-ar-usut</td>
</tr>
<tr>
<td>poho</td>
<td>p-ar-oho</td>
</tr>
<tr>
<td>gotol</td>
<td>g-ar-stol</td>
</tr>
<tr>
<td>ṣoplok</td>
<td>ṣ-ar-oplok</td>
</tr>
<tr>
<td>ṣuliat</td>
<td>ṣ-ar-uliat</td>
</tr>
<tr>
<td>tuwaŋ</td>
<td>t-ar-uvwə</td>
</tr>
<tr>
<td>masak</td>
<td>m-ar-asak</td>
</tr>
</tbody>
</table>

b. ṣirit | ṣ-al-iri | ‘cut’ |
| nugar  | n-al-ugər| ‘dig up’|
| tʃombrek | tʃ-al-ɔmbrek | ‘cold’ |
| botʃor | b-al-ɔtʃor | ‘leaking’ |
| biʃhar | b-al-cbdhar | ‘rich’ |
| horman | h-al-ɔrmɔn | ‘respect’ |

A similar process affects the adjectival suffix -alis in Latin, where /l/ dissimilates to [r] if the preceding stem contains another /l/.

(40) | | |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>navaːlis</td>
<td>‘naval’</td>
</tr>
<tr>
<td>solaːris</td>
<td>‘solar’</td>
</tr>
<tr>
<td>lupanaːris</td>
<td>‘whorish’</td>
</tr>
</tbody>
</table>

Dissimilation of aspiration is attested in other languages such as Manipuri. In (41), the first consonant of the directional suffixes -tʰok and -khət deaspirates if preceded by another aspirate or h (and if the immediately preceding segment is a vowel or sonorant, the consonant becomes voiced).

(41) | | |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>pi-tʰok</td>
<td>‘give out’</td>
</tr>
<tr>
<td>ca-tʰok</td>
<td>‘go out’</td>
</tr>
<tr>
<td>kʰik-tok</td>
<td>‘sprinkle out’</td>
</tr>
<tr>
<td>hut-tok</td>
<td>‘bore out’</td>
</tr>
<tr>
<td>kʰoj-dok</td>
<td>‘trim out’</td>
</tr>
<tr>
<td>tʰin-dok</td>
<td>‘pierce out’</td>
</tr>
<tr>
<td>pi-kʰat</td>
<td>‘give upwards’</td>
</tr>
<tr>
<td>ca-kʰat</td>
<td>‘go upwards’</td>
</tr>
<tr>
<td>kʰik-kʰat</td>
<td>‘sprinkle upwards’</td>
</tr>
<tr>
<td>hut-kʰat</td>
<td>‘bore upwards’</td>
</tr>
<tr>
<td>kʰoj-gʰat</td>
<td>‘trim upwards’</td>
</tr>
<tr>
<td>tʰin-gʰat</td>
<td>‘pierce upwards’</td>
</tr>
</tbody>
</table>

Many Bantu languages such as Kuria 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 underlingly /okɔ/, as well as the second-singular object prefix /ko/ and the (diminutive) object prefix /kɔ/. The data in (42a) motivate the underlying prefix /okɔ/ and (42b) shows application of dissimilation to the prefix. (42c) shows the object prefixes /ko/ and /kɔ/ which also dissimilate, and (42d) shows the contrasting prefixes /go/ and /gɔ/ which have underlingly voiced consonants, and do not assimilate.
The language Chukchi has a number of dissimilatory processes. One of these dissimilates nasality, by changing ɣ to ɣ before a nasal.

A second dissimilation in the language changes the first in a sequence of identical fricatives to a stop.

An important feature of this rule is that only homorganic clusters dissimilate. Other combinations, such as, ɣɣ, ɣl, or ɣɬ, remain unchanged.

Finally the glide ɣ dissimilates to ɣ before a coronal consonant.
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 /ɒ/. This process affects the causative prefix /ga/, seen below.

(47) ga-repa ‘approach it’  ga-beʃi ‘heat it’
     ga-siwe ‘make it stand’ ga-sere ‘make it hit’
     ge-bbaro ‘bend it’  ge-maki ‘give birth to him’
     ge-mowe ‘erase it’  ge-tɔtɔwe ‘support it’
     ge-wasir ‘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’
     /doj-a:/ → duja: ‘to give’
     /doj-u/ → doju ‘give!’
     /doj-i/ → doji ‘gift’

Examples of low vowel dissimilating to nonlow 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 nonhigh near other high vowels.

7.2.3 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-ɔ     ip-k’o     ‘wear’
     kapb-a     kap-k’o     ‘pay back’
     tat-ɔ     tat-k’o     ‘close’
     putb-ɔ     put-k’o     ‘adhere’
     t’otb-a     t’ot-k’o     ‘follow’
     mak-ɔ     mak-k’o     ‘eat’
     tak’-a     tak-k’o     ‘polish’

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, /ʃ/, i.e. the voiceless coronal nonaffricates. 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’
    t’oarvuuf       t’oarvuuf-in ‘antlers and skullcap’
    gahpir           gahpir-in     ‘cap’
    heevemæahhtun   heevemæahhtun-in ‘inappropriate’
    varit            varit-in      ‘2-year-old reindeer buck’
    t’uojvvat        t’uojvvat-in ‘yellow-brown reindeer’
    ahhkut           ahhkub-in     ‘grandchild of woman’
    lottæ:j          lottæ:d:j-in ‘small bird’
    suohkat          suohkað-in     ‘thick’
    jæ:ʔmin          jæ:ʔmim-in    ‘death’

It is interesting that Saami also neutralizes laryngeal contrasts finally, so
voiced stops become voiceless: it is unknown whether a language may
exhibit neutralization of place contrasts without also having neutraliza-
tion of laryngeal contrasts.

### 7.3 Prosodically based processes

A second major class of phonological processes can be termed “prosodi-
cally motivated processes.” Such processes have an effect on the structure
of the syllable (or higher prosodic units such as the “foot”), usually by
inserting or deleting a consonant, or changing the status of a segment
from vowel to consonant or vice versa.

**Vowel sequences.** 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 com-
bination 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 accom-
panied with a lengthening of the surviving vowel, a phenomenon known
as compensatory lengthening. For example, in Matuuumbi, 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’     mj-oótó     ‘fires’
    li-kuguúnda    ‘filtered beer’ lj-oowá     ‘beehive’
    ki-kálaango    ‘frying pan’ kj-uúlá     ‘frog’
    i-kálaango     ‘frying pans’ j-uúlá     ‘frogs’
    lu-toóndwa     ‘star’       lw-aaté     ‘banana hand’
    ku-suúle       ‘to school’ kw-issiwá     ‘to the islands’
    mu-kikálaango  ‘in the frying pan’ mw-iikálaango ‘in the frying pans’

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.
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-ôtô ‘little fire,’ ma-owá ‘beehives,’ ka-ûlã little frog,’ atê ‘banana hands,’ ipokô ‘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 Matuumbi as well, where the combinations /au/ and /ai/ become [oo] and [ee]. This rule is optional in Matuumbi, so the uncoalesced vowel sequence can also be pronounced (thus motivating the underlying representation).

Vowel epenthesis. 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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(52) a-i-têlíike ee-têlíike ‘he cooked them’
     pa-û-kaáitité poó-kaáítité ‘when you cut’
     pa-bá-i-kaáitité pa-bee-kaáitité ‘when they cut them’
     a-u-kaáitite oo-kaáítite ‘he cut it’
     ka-u-toomboóka koo-toombóka ‘when it was falling’
     pa-i-taábu pee-taábu ‘where the books are’
     pa-u-tiítli poo-tíííli ‘where the chicken louse is’
     ka-u-mejá kooméjá ‘little white ant’
     na-u-taáãpu noo-t’aãpu ‘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 Makonde, word-final /a/ deletes before an initial vowel, cf. lîpetã engangaŋa → lîpet ængangaŋa ‘the knapsack, cut it!’, likuka engangaŋa → likuk ængaŋgaŋa ‘the trunk, cut it!’, nmeemba îdanaao → nmeem âdanaoo ‘the boy bring him!’.

<table>
<thead>
<tr>
<th>Continuous</th>
<th>Causative</th>
</tr>
</thead>
<tbody>
<tr>
<td>hula</td>
<td>hulna</td>
</tr>
<tr>
<td>jara</td>
<td>jarna</td>
</tr>
<tr>
<td>woja</td>
<td>wojna</td>
</tr>
<tr>
<td>dû:la</td>
<td>dû:lna</td>
</tr>
<tr>
<td>wurto</td>
<td>wurtina</td>
</tr>
<tr>
<td>wudda</td>
<td>wuddina</td>
</tr>
<tr>
<td>jotto</td>
<td>jottina</td>
</tr>
</tbody>
</table>
Another form of vowel epenthesis is one that 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)  
<table>
<thead>
<tr>
<th>Infinitive</th>
<th>Past</th>
<th>Infinitive</th>
<th>Past</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. hàm-à</td>
<td>hám</td>
<td>’yawn’</td>
<td>dàn-à</td>
</tr>
<tr>
<td>skwàl-à</td>
<td>skwál</td>
<td>’want’</td>
<td>vèr-à</td>
</tr>
<tr>
<td>lòhàj-à</td>
<td>lòhàj</td>
<td>’fear’</td>
<td>làw-à</td>
</tr>
<tr>
<td>b. gòb-à</td>
<td>gòbò</td>
<td>’answer’</td>
<td>kàd-à</td>
</tr>
<tr>
<td>làb-à</td>
<td>làbò</td>
<td>’tell’</td>
<td>dìg-à</td>
</tr>
<tr>
<td>git-à</td>
<td>gitò</td>
<td>’sweep’</td>
<td>?òk-à</td>
</tr>
<tr>
<td>sàp-à</td>
<td>sàpò</td>
<td>’chase’</td>
<td>vòt-à</td>
</tr>
<tr>
<td>vònàh-à</td>
<td>vònàhò</td>
<td>’vomit’</td>
<td>hàs-à</td>
</tr>
<tr>
<td>dòv-à</td>
<td>dòvò</td>
<td>’put’</td>
<td>bàγ-à</td>
</tr>
</tbody>
</table>

Another factor motivating epenthesis is word size, viz. the need to avoid monosyllabic words. One example is seen in the following data from Mohawk, where the first-singular prefix is preceded by the vowel i only when it is attached to a monosyllabic stem.

(55)  
<table>
<thead>
<tr>
<th>Saami</th>
<th>Norwegian</th>
</tr>
</thead>
<tbody>
<tr>
<td>k-atirút-ha?</td>
<td>’I pull it’</td>
</tr>
<tr>
<td>k-ataʔkeràhkwa?</td>
<td>’I float’</td>
</tr>
<tr>
<td>k-kétskw-as</td>
<td>’I raise it’</td>
</tr>
<tr>
<td>k-hní:nus</td>
<td>’I buy’</td>
</tr>
<tr>
<td>k-tat-s → ìktats</td>
<td>’I offer it’</td>
</tr>
<tr>
<td>k-ja-s → ìkjás</td>
<td>’I put it’</td>
</tr>
<tr>
<td>k-ket-s → ìkkets</td>
<td>’I scrape it’</td>
</tr>
</tbody>
</table>

The adaptation of loanwords into North 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)  
<table>
<thead>
<tr>
<th>Saami</th>
<th>Norwegian</th>
</tr>
</thead>
<tbody>
<tr>
<td>daæ:jgi</td>
<td>deig</td>
</tr>
<tr>
<td>nijbi</td>
<td>kniv</td>
</tr>
<tr>
<td>vowʔna</td>
<td>vogn</td>
</tr>
<tr>
<td>muwra</td>
<td>mur</td>
</tr>
</tbody>
</table>

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 stress is not marked in the orthography.

(57) **Suami**       **Norwegian**
di:sdat          'tirsdag          ‘Tuesday’
kæ:wrret         ‘kavring        ‘rusk’
akaøemihkar      aka demiker    ‘academic’
mini:star         mi nister      ‘minister’
teahter          te’ater         ‘theater’
temhpel          ‘tempel         ‘temple’
orgel            ‘orgel         ‘organ’
profes:sor        pro fessor    ‘professor’
plæ:star         ‘plaster       ‘plaster’
kæ:hkul          ‘kakkel        ‘glazed tile’

The above examples are ambiguous in analysis, since the source word is both polysyllabic and has a nonfinal 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)  hote:llo          ho tel          ‘hotel’
marato:na         mara ton        ‘marathon’
universite:hta    universi tet  ‘university’
table:la          ta bell         ‘(time-)table’
privæ:hta         pri vat         ‘private’
kame:la           ka mel          ‘camel’
polæ:ra           po lar          ‘polar’

**Onset creation.** Consonants can also be inserted. The main cause of consonant insertion is the avoidance of initial vowels or vowel sequences. In Arabic all syllables begin with a consonant, and if a word has no underlying initial consonant a glottal stop is inserted, thus /al-walad/ → [ʔalwalad] ‘the boy.’ In the Hare and 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]jõdee        ‘Brother (in church)’
n-anaj                ‘your (sg) sister-in-law (man speaking)’
[h]anaj                ‘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.’
Cluster reduction. 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 simplification is found in Korean.

(60)  

\begin{tabular}{l l l}
\textbf{Imperative} & \textbf{Conjunctive} & \textbf{Indicative} \\
palp-a & pal-k’o & pal-t’a & ‘tread on’ \\
ułph-α & ul-k’o & ul-t’a & ‘chant’ \\
ilk-α & 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’ \\
\end{tabular}

Another cause of cluster simplification is the avoidance of certain specific types of consonant clusters. Shona avoids clusters of the form Cj, although Cw is perfectly acceptable. The deletion of j 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. Where this would result in a Cy sequence, the glide is deleted.

(61)  

\begin{tabular}{l l l}
\textbf{Class} & \textbf{Imperative} & \textbf{Conjunctive} \\
3 & palp-a & pal-k’o \\
18 & ulph-α & ul-k’o \\
17 & ilk-α & il-k’o \\
11 & halth-a & hal-k’o \\
9 & talm-a & tam-k’o \\
6 & anc-a & an-k’o \\
7 & ’this’ & ‘my’ \\
8 & ‘my’ & ‘this’ \\
10 & Class & ‘my’ \\
\end{tabular}

Since /i-angu/ becomes jangu, it is evident that the vowel i does become a glide before a vowel rather than uniformly deleting.

Stress lengthening and reduction. 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.

(62)  

\begin{tabular}{l}
kú-‘líím-a & ‘to cultivate’ \\
kú-‘lí’m-ííl-a & ‘to cultivate for’ \\
kú-’lí’m-áán-a & ‘to cultivate each other’ \\
kú-‘lí’m-á’n-ííl-a & ‘to cultivate for each other’ \\
kú-‘lí’m-án-ííl-á’n-ííl-a & ‘to cultivate for each other continuously’ \\
\end{tabular}
A related process is the reduction of unstressed vowels, as found in English. From alternations like \( \text{ba} \text{ rem} \text{at} - \text{b} \text{era} \text{ met} \text{rik} - \text{mas} \text{nu} \text{p} \text{owd} - \text{mo} \text{'n} \text{p} \text{alji} \), 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) \( /\text{goro}^\prime \text{d}-\text{ok}/ \rightarrow [\text{gora} \text{dok}] \) ‘cities’ \( /\text{gorod}/ \rightarrow [\text{gora}d] \) ‘city’

\( /\text{poda}-\text{l}/ \rightarrow [\text{podal}] \) ‘he gave’ \( /\text{po}^\prime \text{da}-\text{t}/ \rightarrow [\text{pa} \text{dat}] \) ‘to give’

Reduction of unstressed vowels can go all the way to deletion, so in Palestinian Arabic, unstressed high vowels in an open syllable are deleted.

(64) **Palestinian Arabic**

3sg masc 3sg fem 1sg

‘hamal’ ‘hamalat’ ha’malt ‘carry’

‘katab’ ‘katabat’ ka’tabt ‘write’

‘daras’ ‘darasat’ da’rast ‘study’

‘f’irib’ ‘f’irbat’ f’ribt ‘drink’

‘nizil’ ‘nizlat’ n’zilt ‘descend’

‘f’ihim’ ‘fiham’ ‘f’himt ‘understand’

**Syllable weight limits.** 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/ şaphin şapk’a şa:pal şa:pit ‘burn’

wonhin wonk’o wo:nol wo:nit ‘hide’

A typical explanation for this pattern is that long vowels contribute extra "weight" to a syllable (often expressed as the *mora*), and syllable-final consonants also contribute weight. Languages with restrictions such as those found in Yawelmani are subject to limits on the weight of their syllables.

**Stress patterns.** Stress assignment has been the subject of intensive typological study and has proven 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) ‘tiralk’ ‘saliva’ ‘mere pet’ ‘beard’

‘jangar mata’ ‘the Pleiades’ ‘langka, rate, i’ ‘prawn’

‘wele, pene, manta’ ‘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)  
wu’le  ‘tomorrow’
ği panto  ‘year’
elumu ju  ‘give us’
e’lua, enew  ‘he will give me’
ki’muba, luwu, laj  ‘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)  
ğin’tip  ‘bee’
ku’l’pu  ‘hair of arm’
ut’luam’it  ‘mist’
aku’n’ete’pal  ‘times’

Finally, Warao places the main stress on the penultimate syllable and has secondary stresses on alternating syllables before.

(69)  
jî’wara’ne  ‘he finished it’
japu’rukî’tane’hase  ‘verily to climb’
e’naho, roa’haku’tai  ‘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 if the penult is heavy and the final syllable is light, and to the antepenult otherwise. The typical definition of a heavy syllable is one with either a long vowel or 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)  
rad’joo  ‘radio’
ka’tabt  ‘I wrote’
’qarat  ‘she read’
qa’reetum  ‘I read them’
’katbat  ‘she wrote’
qa’reethum  ‘I read’
’qara  ‘he read’
ka’tabna  ‘we wrote’
’katabu  ‘they wrote’
ma kata’batʃ  ‘she didn’t write’

7.4 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 alveopalatalals ($k \rightarrow t$) 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, f\}. Only by contrasting attested with imaginable but unattested phenomena do theories become of scientific interest.

**Impossible rules.** There is a clear and justified belief among phonologists that the rule \(\{s, m\} \rightarrow \{l, k\}/ \{w, f\}\) is “unnatural,” and any theory which predicts that such a rule is on a par with regressive voicing assimilation would not be a useful theory. We have seen in chapter 3 that it is actually impossible to formulate such a process given the theory of distinctive features, since the classes of segments defining 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 innumerable other conceivable 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 technical sense expressed by feature theory. Whether a rule is possible or impossible must be determined in the context of a specific theory.

Another pair of rules which we might wonder about are those in (71).

\[
\begin{align*}
\text{(71) a.} & \quad \text{mt}^f \rightarrow \text{nt}^f & \eta^f \rightarrow \eta^f \\
& \text{np} \rightarrow \text{mp} & \text{np} \rightarrow \text{mp} \\
& \eta k \rightarrow \eta k & \eta k \rightarrow \eta k \\
& \eta t \rightarrow \eta t & \eta t \rightarrow \eta t \\
\text{b.} & \quad \text{mt}^f \rightarrow \text{nt}^f (\text{not } \eta t^f) & \eta^f \rightarrow \eta^f \\
& \text{np} \rightarrow \eta p & \text{np} \rightarrow \text{mp} \\
& \eta k \rightarrow \eta k & \eta k \rightarrow \eta k \\
& \eta t \rightarrow \eta t & \eta t \rightarrow \eta t
\end{align*}
\]

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” is so close that some people may assume that commonly occurring rules are by definition phonetically natural, and unattested rules are 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 temporarily forgo a detailed analysis of how these processes can be formulated – this is taken up in chapter 9 – but in one theory, the so-called linear theory practiced in the 1960s and 1970s, there was also no formal explanation for this difference and the rules in (b) were possible, using feature variable notation. By contrast, the nonlinear theory, introduced in the late 1970s, has a different answer: formalizing such rules is technically impossible, just as writing a rule \( s, m \rightarrow \{l, k\}/\_\{w, f\} \) is impossible in classical feature theory. The mechanism for processes where the output has a variable value (i.e. the result can be either [+anterior] or [−anterior]) requires the target segment to take the same values for the features, and to take on all values within certain feature sets. The alternation in (b) does not have this property (for example, the change of /\( mp \)/ to /\( np \)/ does not copy the feature [labial]), and therefore according to the nonlinear theory this is an unformalizable rule. The process is (correctly) predicted to be unattested in human language.

Unlikely rules. Now consider a rule \( p \rightarrow t^i/._i \), which seems hardly different from \( k \rightarrow t^i/._i \), except the latter is common, and the former 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 nonlinear theories, these are both technically possible rules. One legitimate strategy is to assume that this is an accidental gap, and hope that further research will eventually turn up such a rule. Given that only a tiny fraction of the world’s languages have been surveyed, this is reasonable. There is a bit of danger in assuming that the apparent non-existence of labial coronalization is an accidental gap, because we don’t want to mistakenly ignore the nonexistence of the imaginary rule /s, m/ \( \rightarrow \{l, k\}/\_\{w, f\} \) 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:

\[
\begin{align*}
(72) & \quad p \rightarrow t^i/._i & p, b \rightarrow t^i, d^i/._i \\
& \quad p \rightarrow t^i/._i, e, etc. & p, f, b \rightarrow t^i, f, d^i/._i, e, etc.
\end{align*}
\]

If the rules /p/ \( \rightarrow [t^i]/._i \), /p/ \( \rightarrow [t^i]/._i, e \) and /p, f, b/ \( \rightarrow [t^i, f, d^i]/._i \) were all attested and only the rule /p, b/ \( \rightarrow [t^i, d^i]/._i \) were missing, there would be no question that this is an accidental gap. The number of rules which can be formulated in standard theories is large, running in the millions or billions. If we can’t find one or some dozen particular rules in the

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.


hundred or so languages that we have looked at, this shouldn’t cause serious concern because the chance of finding any one rule out of the set of theoretically possible rules is fairly low, and this one gap is of no more significance than a failure to toss a million-sided coin a few hundred times and not have the coin land with side number 957,219 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 to 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 are still not very high.

The situation with the rule /s, m/ → [l, k] / _[w, f] is quite different. This rule is a representative of an immense class of imaginable rules formed by arbitrarily combining sounds in lists. If rules are unstructured collections of segments changing randomly in arbitrary contexts, then given a mere 8,192 (≈2^{13}) imaginable language sounds, there are around 10^{45,000} different ways to arrange those segments into rules of the type {..} → {..} / _{..}, in comparison to around a billion ways 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, f], and yet not a single one of these rules has been attested. Probability theory says that virtually every attested rule should be of this type, given how many of the imaginable arbitrary rules there are. This is why the lack of rules of the type /s, m/ → [l, k] / _[w, f] is significant – it represents the tip of a mammoth iceberg of failed predictions of the “random phoneme” theory of rules.

Another way to cope with this gap is to seek an explanation outside 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 average 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 the domain of phonological theory itself for the lack of labial coronalization in the set of attested rules.

What 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 common change k → t[i] / _{i, e}. In a vast number of languages, there is some degree of fronting of velar consonants to [k] 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 most 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'i], 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] than like [c] ([k] has a lower formant frequency for the consonant release burst), and [tʃ] sounds more like [t] or [tʃ] (in having a higher burst frequency) than like [k], which is physiologically more similar to. The acoustic similarity of alveopalatals like [tʃ] and palatals like [tʃ] 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] ~ [tʃ] as the alternation [k] ~ [tʃ].

Explaining why k ~ tʃ/(_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 [tʃ]. 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 /kl/. 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 [tʃ]-like release will result, but this will not happen simply as a response to a small physically motivated change, as it does with /kl/. Thus the probability of such a change – p ~ tʃ – 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. Velars and alveolars involve the tongue as their major articulator, as does [tʃ], 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 labials never become linguals: they typically do in nasal assimilation. In fact, there is a 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 Swati.
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 [pɯ], 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 [pʃ]. The place of articulation of the velar release shifts further forward depending on the language and dialect, being realized as [pʃ] in Pedi, or as [pʃ] in Sotho, and finally as [tʃ] in Nguni. So what seems like a quite radical change, given just the underlying-to-surface relation /p/ → [tʃ] 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 – is the question of the extent to which phonological theory should explicitly include reference to concepts rooted in phonetics, such as ease of articulation, perceptibility, 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.

Summary

The distinction between unattested, rare, and well-known patterns in phonology has been important in the development of theory. How do we distinguish between actually nonexistent patterns and patterns that we are unaware of? Which unattested patterns should the formal theory preclude? Why are certain patterns found in very many languages? Should the formal theory try to account for frequency of occurrence? These questions will remain vital research topics in phonology for many years.

Further reading

CHAPTER 8

Abstractness and psychological reality

PREVIEW

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?”

KEY TERMS
- abstractness
- absolute
- neutralization
- psychological reality
- external evidence
A fundamental question in the theory of phonology has been “how abstract is phonology?” specifically, how different can the underlying and phonetic forms of a word be? The essential question is whether grammars use entities that are not directly observed. Related to this is the question whether a linguistic model requiring elements that cannot be directly observed reflects what the human mind does. 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 [kʰɔrts] courts and [kʰɔwdz] codes would be /kʰɔrst-s/ and /kʰɔwd-z/. Such an extremely surface-oriented view of phonology would ignore the fact that the words have in common the plural morpheme, whose pronunciation varies according to the environment. By hypothesizing that the underlying form of [kʰɔrts] is /kʰɔrt-z/, we can say that the plural pronounced s in [kʰɔrts] and the plural pronounced z in [kʰɔwdz] are one and the same thing. Such abstractness in phonological analysis yields the benefit of explaining the similarities in pronunciation of the various realizations of the plural morpheme.

### 8.1 Why limit abstractness?

First we must understand what motivates concern over abstractness.

#### 8.1.1 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 /ɬoˈliːj/ to surface [ɡəˈraɡ] 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 proceed by conscious reasoning, it cannot be taken for granted that everyday academic 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 such as generative grammar 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 general cognitive capacity and 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. Distinctive features are one way of making this job easier, since they limit the ways of analyzing data. Universal constraints on abstractness might similarly help a child trying to arrive at an 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 /ɡəˈɹɪʃəʊɡ/ be the underlying form of [ɡəˈɹɪʃəɡ] 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 /dɔɡ/. But faced with the word atom [ˈætəm] and the related word atomic [ˈætəmɪk], 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 [ˈætəm] and [ˈætəmɪk]: an appropriate representation would be [ætəm]. 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], [tʰɔp] are underlyingly /stɔp/, /tʰɔp/, without aspiration, because there is
(by assumption) no underlying aspiration in English. Similarly, we know that the underlying form of [hɪɾɪŋ] hitting is /hɪɾɪŋ/, 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 [waɾ̩] water? Assuming that the flap is not a phoneme in English (there are no minimal or near-minimal pairs contrasting [t] or [d] vs. [ɾ]), this forces us to say that it must be something other than [ɾ]. The word is spelled with r, 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 [war] 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 [wejɾ]). Any number of hypotheses could be set forth – /wær/, /wær/, /wɛd/, /wɛɾ/, /wæɾ/, and so on. Hypotheses like /wæɾ/ and /wəɾ/ 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 argue decisively against hypothetical /waβɾ/, /waγɾ/, and their ilk. First, there is no evidence for a rule in English effecting the change /γ/! [ɾ] or /β/! [ɾ] 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 /waβɾ/ and /waγɾ/, or /waʔɾ/ 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 /wadɾ/ is less abstract 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 /dɾ/ into a flap in this context (consider father, bother, weather which indicate that there cannot be a rule changing /dɾ/ into a flap in some context). Only three hypotheses remain viable: /war/, /waɾ/, and /wadɾ/. None of these hypotheses posits surface nonexistent 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 /warʃ/ because it posits what we assumed to be a nonexistent underlying segment in the language, but we should reconsider that decision, to at least explain our argument for rejecting an underlying flap. Hypothesizing /warʃ/ 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 perhaps 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 at least 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 [ɾ] is restricted. 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 [ɾ] (hit [hit] ~ hitting [hɪtɪŋ]; hide [hajd] ~ hiding [hæjɪŋ]). We can explain the lack of words in English like *[hɪɾ], *[ruwl], *[æfɾ], and *[əɾǽk], if we assume that the flap [ɾ] 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 /ɾ/ 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 restriction on where underlying flaps appear and let the underlying form of [warʃ] be fully concrete. Some theories do not have conditions on underlying forms (Optimality Theory), others do. Something like conditions on underlying forms seems inevitable, since for example there cannot be any words in English of the form sC_i VC_i, hence *slil, *sneen, *spup, *skuck; yet, it is uncertain what status such conditions have in the theory of grammar. The assumption that all regularities about a language must be captured in the grammar has been a fundamental assumption for many theories of phonology, but has also been challenged (see Hale and Rice 2006), so we cannot take it for granted that the grammar is solely responsible for explaining the distribution of the flap in English.

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 7), insofar as [t] is a less marked, i.e. crosslinguistically common, segment than [d]. Whether this reasoning is correct remains to be determined empirically.
8.1.2 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 underlingly the stem ends with /g/. The abstract representation /porog/ for [porok] ‘threshold (nom sg)’ is justified by 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. One might even advance a formal principle regarding abstractness (a principle to this effect was proposed in the theory of Natural Generative Phonology; see Vennemann 1974):

(1) The underlying form of a morpheme must actually be pronounced as such in some surface form containing the morpheme.

The underlying cognitive presupposition of such a principle is that humans only abstract the nature of morphemes by directly selecting from tokens of perceptual experience with that unit.

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,’ /ŋetomi/ ‘lick.’ We are justified in concluding that the first vowel in /daŋob/ is /a/ because it is actually pronounced as such in [mə-ˈdaŋob] 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 [daˈŋobl]. Although each hypothesized underlying vowel can be pronounced in one surface variant of the root or another, no single surface form actually contains both vowels in their unredcued 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 /tæl'græfl/, which explains the surface vowel qualities in ['tæl'græf] and ['təl'græf-i]) and Tonkawa (cf. /picanə/, which is justified based on the surface forms pican-n-o? and we-pcen-o?). Condition (1) also runs into problems in Yawelmani (chapter 6), 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 /ʔaːml/, so that epenthesis turns /ʔaːml-əhi/ into [ʔaːmil-əhi], and shortening turns /ʔaːml-əli/ into [ʔaməl]. The problem for (1) is that /ʔaːml/ can never be pronounced as such, since either the vowel is shortened, or else /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 7). There is a rule devoicing final obstruents, and another rule spirantizing intervocalic voiced stops. These rules result in alternations such as $\text{sek} \, \text{dry (masc)} \sim \text{seko} \, \text{dry (fem)}$ from $\text{sek}l$, versus $\text{sek} \, \text{blind (masc)} \sim \text{se\text{e}o} \, \text{blind (fem)}$ from $\text{seg}l$. The underlying voiced stop $\text{g}$ is not directly attested in any form of the stem $\text{seg}l$, and thus runs afoul of constraint (2).

Another counterexample to (2) is Hehe (chapter 6). That language has a rule assigning H tone to a penultimate vowel that is not also immediately preceded by an H. This rule accounts for the position of the second H tone in words like kú-kam-í-l-a ‘to milk for,’ kú-kam-il-dn-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 an 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-i-a and kú-kam-ú-a, and then the high vowels become glides before a vowel, causing the H tone to be transferred to the final vowel. The important point about these examples is that the assumed vowels of the causative and passive never surface as vowels: they appear only as glides, since by quirks of Hehe morphology, the morphemes -i- and -u- are always followed by a vowel suffix, so they always undergo glide formation.

8.1.3 Case studies in abstract analysis

We will look in depth at two cases of abstract phonological analysis, one from Matuumbi 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 Matuumbi. Matuumbi 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 Matuumbi, and there are two different patterns depending on the nature of the nasal. One such nasal is the prefix /ɲ-/ 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-bomwáná bómwaana 'pointlessly destroy'
ngólóká góloka 'be straight'
ŋ-dʒilůká dʒiluka '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 /ŋ/ causes a following voiceless consonant to become voiced.

(5) **Adjective (cl 9) Verb**

n-dìnika tînîka 'cut'
n-demá.á têma 'chop'
ŋ-dʒapîtʃá tʃapîtʃa 'be clean'

Finally, /ŋ/ causes a following glide to become a voiced stop, preserving the place properties of the glide.

(6) **Adjective (cl 9) Verb**

ŋ-dʒukútá jûkuta 'be full'
ŋ-gwâá.á wá 'die'
ŋ-gwikiljá wîkilja 'cover'

We know that the prefix is underlyingly /ŋ/ because that is how it surfaces before vowel-initial adjectives such as ŋ-epeéši 'light (cl 9),' ŋ-ilípi 'short (cl 9).'</p>

Different effects are triggered by the nasal of the prefix /mu/ which marks second-plural subjects on verbs. This prefix has the underlying form /mu/, and it can surface as such when the following stem begins with a consonant.
A rule deletes the vowel u preceded by m when the vowel precedes a consonant (you observed this rule in chapter 5), 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).

This reveals an important difference between the two sets of postnasal processes. In underlying nasal C sequences such as /ɲ-bomwáaná/ → m-bomwáaná ‘destroyed (cl 9),’ the nasal only assimilates in place of articulation to the following C, but in nasal + consonant sequences derived by deletion of u, the prefixal nasal causes nasalization of a following voiced consonant.

Another difference between /ɲ/ versus /mu/ 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. (The reason for this is that /mu/ first becomes a syllabic nasal m, and nasalization takes place after a syllabic nasal.)

In comparison, class 9 /ɲ/-mimíná/ with the prefix /ɲ/ surfaces as mimíná ‘spilled (cl 9),’ having undergone degemination.

A third difference between /ɲ + 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.

Remember, though, that /ɲ/ causes a following voiceless consonant to become voiced, so /ɲ-tniká/ → ndmiká ‘cut (cl 9).’

Finally, /mu/ causes a following glide to become a nasal at the same place of articulation as the glide.
Underlying /ɲ/, on the other hand, causes a following glide to become a voiced stop, cf. /ɲ-wkiljá/ → /ŋ-gwikiljá/ ‘covered (cl 9).’

The differences between /ɲ/ 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 when /u/ deletes.

On the other hand, /ɲ/ has no effect on the length of a preceding vowel.

Finally, /ɲ/ surfaces as [ŋ] before a vowel and the length of the following vowel is not affected. But /mu/ surfaces as [mw] before a vowel due to a process of glide formation, and the following vowel is always lengthened.

A number of properties distinguish /mu/ from /ɲ/. 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 second-plural verbal subject prefix /mu/ can actually be pronounced as [mu], since deletion of /u/ is optional for this prefix.

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.

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 second-plural 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. 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’
    láábuka  n-naábuká    ‘breakfast’
    d²ììngja  n-ñììngjá    ‘enter’
    góónd³a  n-ñòónd³á    ‘sleep’

It forms a geminate nasal with a following nasal.

(16) **Infinitive**  **Adjective (cl 3)**
    máta  m-matá.á    ‘plaster’
    múlíka  m-múlíká    ‘burn’
    námata  n-námátá    ‘be sticky’

It also does not cause a following voiceless consonant to become voiced.

(17) **Infinitive**  **Adjective (cl 3)**
    pάánda  m-páánda    ‘plant’
    téléka  n-téléká    ‘cook’
    t³óna  n-t³óná.á    ‘sew’
    káalaanga  n-kláaangá    ‘fry’

Another reason to believe that this prefix is underlingly */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  m-wáalíbiká    ‘break’
    épuka  m-weepúká    ‘avoid’
    ímmba  m-múmmbá    ‘dig’
    ótoka  m-wootóká    ‘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 second-plural subject has.

Finally, the data in (19) show that this prefix has the same effect of lengthening the preceding vowel as the second-plural subject prefix has.

(19) mwoógo  ‘cassava’  mwoogoo m-móó    ‘rotten cassava’
     mpilá  ‘football’  mpiláa m-puwáaniiká    ‘broken football’
     nkóta  ‘sweets’  nkotaa n-nogá.á    ‘good sweets’
     nkýa  ‘spear’  nkýa a n-kóló    ‘big spear’

The only reasonable assumption is that this prefix is underlingly */mu/, despite the fact that the vowel *u* never actually appears as such.
Direct attestation of the hypothesized underlying segment would 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. Thus the fact that the class 3 prefix behaves in all other respects exactly like prefixes which are uncontroversially /mu/ suffices to justify the conclusion that the class 3 prefix is, indeed, /mul/.

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 anywhere in the language. The surface vowels (syllabics) and diphthongs of Sanskrit are in (20).

(20)  a  i  u  r  l  a:  e:  o:  u:  r:  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’
     jadi ‘if’ + i:çwarah ‘lord’  →  jadi: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:çwarah ‘O Lord’  →  se:çwarah  ‘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. There is also a rule shortening a long vowel before another vowel at the phrasal level, which is why at the phrasal level /a:l/ plus /i/ does not form a long diphthong [a:i].
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) \( \text{bhar-at-i 'he bears'} \quad \text{a-bhar-at 'he bore'} \)
\( \text{tuŋ-at-i 'he urges'} \quad \text{a-tuŋ-at 'he urged'} \)
\( \text{wardh-at-i 'he grows'} \quad \text{a-wardh-at 'he grew'} \)

If the stem begins with the vowel \( a \), the prefix \( a- \) combines with following \( a \) to give a long vowel, just as \( a + i, a + u / \) at the phrasal level.

(24) \( \text{aŋ-at-i 'he drives'} \quad \text{a:j-at 'he drove'} \)
\( \text{aŋc-at-i 'he bends'} \quad \text{a:jc-at 'he bent'} \)

When the root begins with the vowels \( i, u \), the resulting sequences \( ai(\cdot), au(\cdot) \) surface as long mid vowels:

(25) \( \text{il-at-i 'he is quiet'} \quad \text{e:l-at 'he was quiet'} \)
\( \text{i:kş-at-i 'he sees'} \quad \text{e:kş-at 'he saw'} \)
\( \text{ukş-at-i 'he sprinkles'} \quad \text{o:kş-at 'he sprinkled'} \)
\( \text{ubş-at-i 'he forces'} \quad \text{o:by-at 'he forced'} \)

These alternations exemplify the rule where \( /ai, au/ \rightarrow [e:, o:] \).

We 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. \( \text{ca 'and' + oːkşat 'he sprinkled'} \rightarrow \text{caːukşat 'and he sprinkled'} \)
\( \text{ca 'and' + eːkşat 'he saw'} \rightarrow \text{caːıkşat 'and he saw'} \)

b. \( \text{ca 'and' + uːkšati 'he sprinkles'} \rightarrow \text{coːkšati 'and he sprinkles'} \)
\( \text{ca 'and' + iːkšati 'he sees'} \rightarrow \text{ceːkšati 'and he sees'} \)

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 \( \text{caːukşat} \) and \( \text{caːıkşat} \) are \( \text{ca#a-ukŞat} \) and \( \text{ca#a-ıkŞat} \). The surface long diphthong derives from the combination of the sequence of \( a's \) into one long \( a:\).

The same pattern holds for all words beginning with mid vowels, even when there is no morphological justification for decomposing \( [e:, o:] \) into \( /a+i, a+u/ \).

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 \( [j, w] \) before another vowel, which applies at the phrasal level in the following examples.
The mid vowels [e:, o:] become [aj, aw] before another vowel (an optional rule, most usually applied, can delete the glide in this context, giving a vowel sequence).

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 /jadi#aham/ does), giving [wanaj#a:ste:].

Abstractness in English. Now we will consider an abstract analysis whose legitimacy has been 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 classic case of questionable abstractness is the analysis of English [ɔj] proposed in Chomsky and Halle 1968 (SPE), that [ɔj] 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 /īū/ and so forth represent tense vowels in the transcription used there.

The first step in arguing for this representation is to defend the assumption that [aj], [aw], [ij], [uw], [ej], [ow] derive from /iː, uː, iː, oː, iː, oː/, and /ā/. The claim is motivated by the Trisyllabic Laxing alternation in English which relates the vowels of divine ~ divinity ([a]j ~ [i]), profound ~ profundity ([aw] ~ [a]), serene ~ serenity ([i]j ~ [e]), verbose ~ verbosity ([ow] ~ [s]), and sane ~ sanity ([ej] ~ [æ]). These word pairs are assumed to be morphologically related, so both words in the pairs would have 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

\[
\begin{align*}
\text{e:ti} 'he comes' + \text{r̥i} 'seer' & \rightarrow \text{e:ti} \text{r̥i} \\
\text{jadi} 'if' + \text{aham} 'I' & \rightarrow \text{jad} \text{i} \text{aham} \\
\text{jadi} 'if' + \text{a:dit:ja:h} 'sons of Aditi' & \rightarrow \text{jad} \text{j} \text{a:dit:ja:h} \\
\text{e:ti} 'she comes' + \text{uma}: 'Uma' & \rightarrow \text{e:ti} \text{uma}: \\
\text{bhwatu} 'let it be' + i:çwarah 'Lord' & \rightarrow \text{bhwatw} i:çwarah \\
\text{sadhu} 'well' + \text{e:ti} 'he comes' & \rightarrow \text{sadhw} \text{e:ti} \\
\end{align*}
\]

\[
\begin{align*}
\text{prabhō} 'O Master' + \text{e:ti} 'he comes' & \rightarrow \text{prabhaw} \text{e:ti} \\
\text{wane} 'in the forest' + \text{a:ste:} 'he sits' & \rightarrow \text{wanaj} \text{a:ste:} \\
\text{wane} 'in the forest' + \text{e:ti} 'he comes' & \rightarrow \text{wanaj} \text{e:ti} \\
\text{prabhō} 'O Master' + o:kṣat 'he sprinkled' & \rightarrow \text{prabhaw} o:kṣat \\
\end{align*}
\]
vowel agreeing in backness with that vowel. By those rules (and a few others), /sǣn/ becomes [sējn], /serēn/ becomes [sərējn], and /dīvēn/ becomes [dəvəjn]. By the Trisyllabic Laxing rule, when a tense vowel precedes the penultimate syllable of the word the vowel becomes lax, which prevents the vowel from shifting in height (shifting only affects tense vowels). Accordingly, /dəvəjn/ and /dəvəniti/ share the root /dəvēn/. In /dəvēniti/, the tense vowel /i/ instead undergoes Trisyllabic Laxing, and therefore surfaces as [i].

In this way, SPE reduces the underlying vowel inventory of English to /i/, /u/, /e/, /æ/, /a;, plus the diphthong /aj/. 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 [œ]. It is then surmised that this gap in the system of tense vowels, and the remaining diphthong, can be explained away simultaneously, if [aj] derives from underlying /œ/. Furthermore, given the system of rules in SPE, if there were an underlying vowel /œ/, it would automatically become [aj].

Briefly, /œ/ undergoes diphthongization to become œj because œ is a front vowel and the glide inserted by diphthongization has the same backness as the preceding tense vowel. The vowel œ is subject to backness readjustment which makes front low vowels [+back] before glides (by the same process, æj which derives from /i/ by Vowel Shift becomes [ay]). Since hypothesized /œ/ does not become *[ø], and must remain a low vowel in order to undergo backness adjustment, Vowel Shift must not apply to /œ/. 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 [aj] 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 [aj] from /œ/ 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 analyze 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 [aj] comes from /œ/, 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, Matuumbi, Hehe, and Sanskrit. No such advantage accrues to an abstract
analysis of [ɔj] in English. The only potential alternations involving [ɔj] are a few word pairs of questionable synchronic relatedness such as joint ~ juncture, point ~ puncture, ointment ~ unctuous, boil ~ bouillon, 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 nonexistent vowel [œ], and deriving the mixture of observed vowels [ʌ], [o], [uw], [ow], or [ij] from [œ] would require rather ad hoc rules. The hypothesized underlying vowel system /i u e t æ ɔ 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 nonlow front round vowels. This typological implicational principle would be violated by this abstract analysis of English, which has no underlying /y, ø/: in other words, idealizations about underlying forms can conflict.

An important aspect of the argument for [ɔj] as /œ̄/ is the issue of independent motivation for the rules that would derive [ɔj]. The argument for those rules, in particular Vowel Shift, is not ironclad. Its motivation in synchronic English hinges on alternations of the type divine ~ divinity, profound ~ profundity, but these alternations are lexically restricted and totally unproductive in English (unlike the phonological alternations in the form of the plural suffix as well as the somewhat productive voicing alternation in life ~ lives). A consequence of the decision to analyze all cases of [aj] as deriving from /i/ 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 account for the contrast between contrite ~ contrition, where /i/ becomes lax and t ~ [ʃ], versus right ~ righteous, where there is no vowel laxing and t ~ [tʰ], it was claimed that the underlying form of right is /rixt/, and rules are developed whereby /ixC/ → [ajC]. Abstract /x/ is called on to explain the failure of Trisyllabic Laxing in the word nightingale, claimed to derive from /nixtVngel/. To explain the failure of Trisyllabic Laxing in words like rosary, it is assumed that the final segment is /j/ and not /i/, viz. /rɔ̄sVrj/. Other examples are that the contrast between veto (with no flapping and a secondary stress on [o]) vs. motto (with flapping and no stress on [o]) was predicted by positing different vowels – /maol/ vs. /vēts/, even though the vowel qualities are surface identical. Words such as relevance are claimed to contain an abstract nonhigh front glide, whose function is to trigger assimilation of /t/ and then delete, so relevance would derive from /relevante/, the symbol /e/ representing a nonsyllabic nonhigh front vocoid (a segment not attested in any language to date).

It is not enough to just reject these analyses as being too abstract, since that circularly answers the abstractness controversy by fiat. We need to pair any such 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 phonological analysis is that underlying representations allow related words to be derived from a unified source by rules. The concept “related word” needs to be scrutinized carefully, because liberally assuming that “related words” have common underlying forms can yield very abstract analyses.

**Word-relatedness.** Consider word pairs such as happy/glade, 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 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 are related historically, but the connection is known only to students of the history of English. The words father and paternal are related semantically and phonologically, but this does not mean that we can derive father and paternal from a common root in the grammar of English. It may be tempting to posit relations between choir and chorus, shield and shelter, or hole and hollow, but these do not represent word-formation processes of modern English grammar.

The concept of “relatedness” that matters for phonology is in terms of morphological derivation: if two words are related, they must have some morpheme in common. It is uncontroversial that words such as cook and cooked or book and books are morphologically related in a synchronic grammar: the words share common roots cook and book, via highly productive morphological processes which derive plurals of nouns and past-tense forms of verbs. An analysis of word formation which failed to capture this fact would be inadequate. The relation between tall and tallness or compute and computability is similarly undeniable. In such cases, the syntactic and semantic relations between the words are transparent and the morphological processes represented are regular and productive.

Some morphological relations are not so clear: -ment attaches 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, *intervention, *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 it 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, these words may just be listed in the lexicon. If they are, 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 root, rather than being phonologically and semantically similar pairs of words, which are nevertheless entered as separate and formally unrelated lexical items. The question of how to judge formal
word-relatedness remains controversial to this day, and with it, many issues pertaining to phonological abstractness.

8.2 Independent evidence: historical restructuring

Paul Kiparsky’s seminal 1968 paper “How abstract is phonology?” raises the question whether limits on abstractness are possible and desirable. Kiparsky’s concern is the postulation of segments which are never realized, where a language is assumed to have an underlying distinction between two segments which are always phonetically merged. A classic example is Hungarian, which has a vowel harmony rule where suffix vowels agree with the preceding vowel in backness, e.g. *haz-am ‘my house,’ *fylem ‘my ear,’ *vi:z-em ‘my water.’ A small number of roots with the front vowels [i: i e:] always have back vowels in suffixes, e.g. *hej-am ‘my rind,’ *pi:lam ‘my arrow.’ The abstract analysis is that these roots have underlying back vowels [ɨɨ:ə], which later become front vowels. This move makes these roots phonologically regular. The reasoning is that since these 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, /ɨɨ/ is always neutralized with /ɨ/. Kiparsky argues that while contextual neutralization is common and has demonstrable psychological reality, absolute neutralization is a theoretically constructed fiction.

In arguing against absolute neutralization, 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 grammatical theories. It is argued that 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 the history of a language, so even if it were shown that Hungarian heːɟ 'rind' and niːɭ 'my arrow' derived from earlier *həɟ and *ɲɨɭ, 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 you can inspect a later stage of a language to learn about 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.

8.2.1 Yiddish final devoicing

The history of Yiddish devoicing is one example of such evidence. 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' ~ taga '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 thirteenth century where the word for '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/ and /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 reappears as voiced. This process where an earlier sound change is dropped from the grammar is known as reversal of sound change: consonants revert to their original state found before the sound change applied.

There are mysterious exceptions to restoration of original voiced consonants. One case is the word gelt 'money,' which derives historically from geld with a voiced consonant. The reason for the different treatments of gelt and tag, words which both ended with voiced consonants at earlier stages of the language, is the difference 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 devoicing rule was added, there were no alternations in gelt so a child would have no reason to assume that the underlying form of the word is anything other than /gelt/. The child never hears geld, and has no reason to think that the underlying form is different from /gelt/. At an even later stage, 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 reanalyzed as /t/ – a reanalysis 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 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 was 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/, since 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’ – vewn ‘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 selection of the underlying form for the adverb, since there is no synchronic connection between the adverb and the noun – no process derives nouns and adverbs from a unified source, so nothing connects the words for ‘way’ and ‘away.’ The divergence of veg and avek in Yiddish points out that you cannot freely assume that any two phonetically and semantically similar words are actually derived from a single underlying form.

8.2.2 Historical evidence and the treatment of absolute neutralization

Kiparsky draws two main conclusions from this and similar cases. First, he points out that in lieu of 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 show the psychological reality of contextual neutralization, since it 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 which 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,’ n:i:l-am ‘my arrow,’ the proposal is that these roots are marked as exceptions to vowel harmony. On the assumption that harmonizing suffixes all contain underlying back vowels, the fact that back vowels appear in suffixes after these roots boils down to 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.

8.3 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, there are internally well-supported cases of absolute neutralization. Two famous cases are Yawelmani discussed by Kisseberth (1969), and Maltese discussed by Brame (1972).

8.3.1 Yawelmani /u:/

Aspects of Yawelmani have been discussed in chapter 6. 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.
Thus the root vowel /o/ has no effect on the suffixes /hin/ and /it/ but causes rounding of /ka/ 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.

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.

In [wo:ʔuj-hun], [do:lul-hun], the second vowel is epenthetic, so these roots underlyingly have the shape CV:CC, parallel to [ʔa:mil-hin] ~ [ʔamlal] ‘help.’

There are problematic roots in (33). Although the stem vowel is a mid vowel, a following nonhigh vowel does not harmonize — they seem to be exceptions. Worse, a high vowel does harmonize with the root vowel, even though it does not even satisfy the basic phonological requirement for harmony (the vowels must be of the same height).

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) illustrate a set of CVCV(C) roots, where, as we noticed before, the two vowels are otherwise identical. In these verbs, the second long vowel is a nonhigh version of the first vowel.
The surface mid vowels of these stems act irregularly for harmony—they do not trigger harmony in mid vowels, so they do not act like other mid vowels. They also exceptionally trigger harmony in high vowels, as only high vowels otherwise do.

When you consider the vowels of Yawelmani—[i e a o u eː oː aː]—you see that long high vowels are lacking in the language. The preceding mysteries are solved if you assume, for instance, that the underlying stem of the verb ‘scorch’ is /tunuːj/. As such, the root would obey the canonical restriction on the vowels of a bivocalic stem—they are the same vowel—and you expect /uː:/ to trigger harmony on high vowels but not on mid vowels, as is the case. A subsequent rule lowers /uː:/ to [oː:], merging the distinction between underlying /oː/ and /uː/.

The assumption that /uː:/ becomes [oː] and therefore some instances of [oː] derive from /uː:/ 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 -aːla and shortens the preceding stem vowel.

We have seen in (33) that the root [c’oːm] 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: these words are not exceptions. Being an exception has a specific meaning, 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’om-al can be treated as exceptionality. But this root does actually trigger vowel harmony, as shown by c’om-ut, and such application is problematic since the rule is applying when the formal conditions of the rule are not even satisfied on the surface. Marking a root as an exception says 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 different – a form is triggering a rule even though it should not. The exceptionality analysis also offers no account of stems such as c’uːjo:-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.

Although the specific segment /uː/ is not pronounced as such in the language, concern over the fact that pronunciations do not include that particular segment would be misguided from the generative perspective, which holds that language sounds are defined in terms of features and the primary unit of representation is the feature, not the segment. All of the features comprising /uː/ – vowel height, roundness, length – are observed in the surface manifestations of the abstract vowels.

8.3.2 Maltese /ʕ/

Another well-supported case of absolute neutralization comes from Maltese. We will just outline the basics of the argument: you should read Brame (1972) to understand the full argument. After outlining some basic phonological processes, we consider examples which seem superficially inexplicable, but which can be explained easily if we posit an abstract underlying consonant /ʕ/.

8.3.2.1 Basic Maltese phonology

Stress and apocope. (36) exemplifies 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 (nonfinal) consonant or one with a long vowel.

(36) séna ‘year’ sultaan ‘king’
   ?attúus ‘cat’ hdüura ‘greenness’
   hátaf ‘he grabbed’ bézaʔ ‘he spat’
   hátf-et ‘she grabbed’ bézʔ-et ‘she spat’
   htáf-t ‘I grabbed’ bzáʔ-t ‘I spat’
   htáf-na ‘we grabbed’ bzáʔ-na ‘we spat’

The second group illustrates apocope, which deletes an unstressed vowel followed by CV. The underlying stem of the word for ‘grabbed’ is /hataf/, seen in the third-singular masculine form. After stress is assigned in third-singular feminine /hátaf-et/, (37) gives surface [hát-e:t].

(37) V → Ø / - CV Apocope
    [--stress]

In /hát-e: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 giving [hát:f].
Unstressed reduction and harmony. Two other rules are unstressed-vowel reduction and vowel harmony. By the former process, motivated in (38), unstressed i reduces to e. The third-singular feminine suffix is underlyingly /-it/, which you can see directly when it is stressed. The underlying form of kìteb 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’ hatf-ìt-kom ‘she grabbed you (pl)’
béz?-et ‘she spat’ bez?-ìt-l-ek ‘she spat at you’
kìteb ‘he wrote’ ktìb-t ‘I wrote’

Thus the following rule is motivated.

(39) i → [+high] unstressed V-reduction
    [-stress]

By vowel harmony, /i/ becomes [o] when preceded by o.

(40) kórob ‘he groaned’ kórb-ot ‘she groaned’
jórob ‘he drank’ jórb-ot ‘she drank’

Surface kórb-ot derives from /korob-it/ by applying stress assignment, the vowel harmony in (41), and apocope.

(41) i → [+round] l V C0 _ Harmony
    [+round]

Epenthesis. The data in (42) illustrate another rule, which inserts [i] before a word-initial sonorant that is followed by a consonant.

(42) láʔat ‘he hit’ rròhos ‘it (masc) became cheap’
láʔat-et ‘she hit’ rròhs-ot ‘it (fem) became cheap’
ilʔát-t ‘I hit’ irrhós-t ‘I became cheap’
ilʔát-na ‘we hit’ irrhós-na ‘we became cheap’
márad ‘he became sick’ néfah ‘he blew’
márd-et ‘she became sick’ néfh-ët ‘she blew’
imrâd-t ‘I became sick’ infâh-t ‘I blew’
imrâd-na ‘we became sick’ infâh-na ‘we blew’

Stress assignment and apocope predict /lâʔat-na/ → /lâʔat-na/: the resulting consonant cluster sonorant plus obstruent sequence is eliminated by the following rule:

(43) Ø → i l # _ [+ sonor] C Epenthesis

Regressive harmony and precoronal fronting. These rules apply in the imperfective conjugation, which has a prefix ni- ‘1st person,’ ti- ‘2nd person’
or ji- ‘3rd person’ plus a suffix -u ‘plural’ for plural subjects. The underlying prefix vowel i is seen in the following data:

(44) ní-msah  ‘I wipe’ tí-msah  ‘you wipe’
    ní-jbah  ‘I resemble’ tí-jbah  ‘you resemble’
    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-hlom  ‘I dream’ tó-hlom  ‘you dream’
    nó-ʔtol  ‘I kill’ tó-ʔtol  ‘you kill’
    nó-rbot  ‘I tie’ tó-rbot  ‘you tie’
    nó-ʔot  ‘I hit’ tó-ʔot  ‘you hit’

This can be explained by generalizing harmony (41) so that it applies before or after a round vowel. The nature of the stem-initial consonant is important in determining whether there is surface 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-ʃrob  ‘I drink’ tí-ʃrob  ‘you drink’

Examples such as nó-bzoʔ show that if the coronal obstruent is not immediately after the prefix vowel, harmony applies. The explanation for apparent failure of harmony is simply that there is a rule fronting o when a coronal obstruent follows.

(47) o → [-back] / -[+cor] [-son]

**Guttural lowering.** Another process lowers ĭ/i/ to a before the “guttural” consonants ? and h:

Treating glottal stop as [+low] is controversial since that contradicts the standard definition of [+low], involving tongue lowering. Recent research in feature theory shows the need for a feature that includes laryngeal glides in a class with low vowels and pharyngeal consonants.

(48) ná-ʔsam  ‘I divide’ tá-ʔsam  ‘you divide’
    ná-ʔbel  ‘I agree’ tá-ʔbel  ‘you agree’
    ná-hrab  ‘I flee’ tá-hrab  ‘you flee’
    ná-hleb  ‘I milk’ tá-hleb  ‘you milk’
This motivates the following rule:

\[(49) \quad i \rightarrow [+\text{low}] / _{-} \text{C} \quad \text{Guttural lowering} \quad [+\text{low}]\]

**Metathesis.** (50) and (51) illustrate another process. When the stem has a medial obstruent, the prefix vowel is stressed and the stem vowel deletes before -\(u\).

\[(50) \quad \text{ní-msah} \quad \text{‘I wipe’} \quad \text{ní-msh-u} \quad \text{‘we wipe’} \quad \text{nó-bzoʔ} \quad \text{‘I spit’} \quad \text{nó-bzʔ-u} \quad \text{‘we spit’} \quad \text{ní-dhol} \quad \text{‘I enter’} \quad \text{ní-dhl-u} \quad \text{‘we enter’} \quad \text{ná-ʔsam} \quad \text{‘I divide’} \quad \text{ná-ʔsm-u} \quad \text{‘we divide’} \quad \text{ná-hdem} \quad \text{‘I work’} \quad \text{ná-hdm-u} \quad \text{‘we work’} \]

This is as expected: underlying /ni-ms\(h\)-u/ is stressed on the first syllable, and the medial unstressed vowel deletes because it is followed by CV. The example [nó\(b\)z\(ʔ\)u] 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. Unstressed \(i\) reduces to \([e]\), so [ní-dneb] derives from /ni-dnib/. The underlying high vowel is revealed when the stem vowel is stressed, as in [níd\(n\)bu].

\[(51) \quad \text{ní-dneb} \quad \text{‘I sin’} \quad \text{ni-dn\(b\)-u} \quad \text{‘we sin’} \quad \text{ní-tlef} \quad \text{‘I lose’} \quad \text{ni-t\(l\)-f-u} \quad \text{‘we lose’} \quad \text{ní-tlob} \quad \text{‘I pray’} \quad \text{ni-t\(l\)-b-u} \quad \text{‘we pray’} \quad \text{nó-krob} \quad \text{‘I groan’} \quad \text{no-kór-b-u} \quad \text{‘we groan’} \quad \text{nó-ʔmos} \quad \text{‘I kick’} \quad \text{no-ʔmóms-u} \quad \text{‘we kick’} \quad \text{ná-\(h\)rab} \quad \text{‘I flee’} \quad \text{na-hár\(b\)-u} \quad \text{‘we flee’} \quad \text{ná-\(h\)raʔ} \quad \text{‘I burn’} \quad \text{na-\(h\)ár\(ʔ\)-u} \quad \text{‘we burn’} \quad \text{ná-ʔleb} \quad \text{‘I overturn’} \quad \text{na-ʔlílb-u} \quad \text{‘we overturn’} \]

Based solely on stress assignment and apocope, as illustrated in (50), we would predict *níd\(n\)bu, *nól\(l\)bu. This again would result in an unattested consonant onset – a sonorant followed by an obstruent – which is avoided by a process of vocalic metathesis whereby ni-t\(l\)-f\(u\) \(\rightarrow\) ni-t\(l\)-f\(u\).

\[(52) \quad \text{V C C V₁ C V} \rightarrow \text{V C V₁ C C V} \quad \text{Metathesis} \quad [+ \text{son}] \]

In some stems which undergo (52), the vowel alternates between \(i\) and \(a\):

\[(53) \quad \text{ní-frah} \quad \text{‘I rejoice’} \quad \text{ni-fírh-u} \quad \text{‘we rejoice’} \quad \text{ní-tlaʔ} \quad \text{‘I leave’} \quad \text{ni-tl\(ʔ\)-u} \quad \text{‘we leave’} \quad \text{ní-sraʔ} \quad \text{‘I steal’} \quad \text{ni-sír\(ʔ\)-u} \quad \text{‘we steal’} \]
The underlying stem vowel is /i/ in these cases. When no vowel suffix is added, underlying /ni-fr/ becomes [ni-frə] by Guttural Lowering (49). When -u is added, metathesis moves underlying /i/ away from the guttural consonant which triggered lowering, hence the underlying vowel is directly revealed.

**Stems with long vowels.** 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 (54):

(54)  
<table>
<thead>
<tr>
<th>Stem</th>
<th>Meaning</th>
<th>Stem</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>dáar</td>
<td>'he turned’</td>
<td>sáar</td>
<td>'it (masc) grew ripe’</td>
</tr>
<tr>
<td>dáar-et</td>
<td>'she turned’</td>
<td>sáar-et</td>
<td>'it (fem) grew ripe’</td>
</tr>
<tr>
<td>dáar-u</td>
<td>'they turned’</td>
<td>sáar-u</td>
<td>'they grew ripe’</td>
</tr>
<tr>
<td>dór-t</td>
<td>'I turned’</td>
<td>sír-t</td>
<td>'I became ripe’</td>
</tr>
<tr>
<td>dór-na</td>
<td>'we turned’</td>
<td>sír-na</td>
<td>'we became ripe’</td>
</tr>
<tr>
<td>dór-tu</td>
<td>'you turned’</td>
<td>sír-tu</td>
<td>'you became ripe’</td>
</tr>
</tbody>
</table>

These stems exhibit a process of vowel shortening where aa becomes o or i (the choice is lexically determined) before a CC cluster.

(55)  
\[ aa \rightarrow o, i / _ CC \]

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.

(56)  
<table>
<thead>
<tr>
<th>Stem</th>
<th>Meaning</th>
<th>Stem</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>in-dúur</td>
<td>'I turn’</td>
<td>in-sír</td>
<td>'I become ripe’</td>
</tr>
<tr>
<td>t-dúur</td>
<td>'you turn’</td>
<td>t-sír</td>
<td>'you become ripe’</td>
</tr>
<tr>
<td>in-súu?</td>
<td>'I drive’</td>
<td>in-zíid</td>
<td>'I add’</td>
</tr>
<tr>
<td>t-súu?</td>
<td>'you drive’</td>
<td>t-zíid</td>
<td>'you add’</td>
</tr>
</tbody>
</table>

From /ni-duur/, you expect stress to be assigned to the final syllable because of the long vowel. Since the vowel of /ni/ is unstressed and in an open syllable, it should delete, giving ndíur. The resulting cluster then undergoes epenthesis.

### 8.3.2.2 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 (57), 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-dúur ‘I turn’ seen in (54).

(57)  
<table>
<thead>
<tr>
<th>Stem</th>
<th>Meaning</th>
<th>Stem</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>ní-sool</td>
<td>'I cough’</td>
<td>ní-sóol-u</td>
<td>'we cough’</td>
</tr>
<tr>
<td>ní-laab</td>
<td>'I play’</td>
<td>ní-láab-u</td>
<td>'we play’</td>
</tr>
<tr>
<td>ní-baat</td>
<td>'I send’</td>
<td>ní-báat-u</td>
<td>'we send’</td>
</tr>
<tr>
<td>nó-ʔood</td>
<td>'I stay’</td>
<td>no-ʔood-u</td>
<td>'we stay’</td>
</tr>
<tr>
<td>nó-ʔood</td>
<td>'I hate’</td>
<td>no-ʔood-u</td>
<td>'we hate’</td>
</tr>
</tbody>
</table>
The location of stress and the retention of the prefix vowel in nóʔood is parallel to the retention of the prefix vowel in other tri-consonantal stems in (44)–(48), such as ni-msah ‘I wipe.’ If the underlying stem of ni-sool had a consonant, i.e. were /sXol/ where X is some consonant yet to be fully identified, the parallelism with ni-msah and the divergence from in-dúur would be explained. The surface long vowel in ni-sool would derive by a compensatory lengthening side effect coming from the deletion of the consonant X in /ni-sXol/.

Another unexpected property of the stems in (57) 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 ni-msh-u ‘we wipe,’ which differ in this respect, and compare ni-sóol-u to ni-fórb-u ‘we drink,’ which are closely parallel. Recall that if the medial stem consonant is a sonorant, expected V-CRC-V instead undergoes metathesis of the stem vowel around the medial consonant, so ni-fórb-u becomes ni-fórb-u (creating a closed syllable which attracts stress). If we hypothesize that the underlying stem is isXol, then the change of /ni-sXol-u/ to ni-sóXl-u (phonetic nísóolu) would make sense, and would further show that X is a sonorant consonant: § qualifies as a sonorant (it involves minimal constriction in the vocal tract).

Another peculiarity is that these long vowels resist shortening before CC:

\[
\begin{align*}
\text{sóol} & \quad \text{‘he coughed’} & \text{sóolt} & \quad \text{‘I coughed’} & \text{sóolna} & \quad \text{‘we coughed’} \\
\text{sóob} & \quad \text{‘he lamented’} & \text{sóobt} & \quad \text{‘I lamented’} & \text{sóobna} & \quad \text{‘we lamented’} \\
\text{ʔáad} & \quad \text{‘he stayed’} & \text{ʔáadt} & \quad \text{‘I stayed’} & \text{ʔáadna} & \quad \text{‘we stayed’} \\
\text{báad} & \quad \text{‘he hated’} & \text{báadt} & \quad \text{‘I hated’} & \text{báadna} & \quad \text{‘we hated’}
\end{align*}
\]

In contrast to examples in (54) 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 consonant in /soXol/, we explain the preservation of the long vowel in [sóolt] if this form derives from sXol-t, where deletion of X (which we suspect is specifically §) lengthens the vowel, and does so after 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, epenthetic i appears when a consonant-initial suffix is added. Compare (59a), where the first consonant is not a sonorant, with (59b), where the first consonant is a sonorant.

\[
\begin{align*}
\text{a.} & \quad \text{ʔáad} & \quad \text{‘he stayed’} & \quad \text{ʔáadt} & \quad \text{‘I stayed’} \\
& \quad \text{báad} & \quad \text{‘he hated’} & \quad \text{báadt} & \quad \text{‘I hated’} \\
& \quad \text{sóol} & \quad \text{‘he coughed’} & \quad \text{sóolt} & \quad \text{‘I coughed’} \\
\text{b.} & \quad \text{máad} & \quad \text{‘he chewed’} & \quad \text{imáadt} & \quad \text{‘I chewed’} \\
& \quad \text{nás} & \quad \text{‘he dozed’} & \quad \text{ínást} & \quad \text{‘I dozed’} \\
& \quad \text{láaʔ} & \quad \text{‘he licked’} & \quad \text{iláaʔt} & \quad \text{‘I licked’}
\end{align*}
\]

The verbs in (59b) behave like those in (42), e.g. láʔat ‘he hit’ ~ ilʔát-t ‘I hit’, where the initial sonorant + C cluster undergoes epenthesis of i.
The forms in (59b) make sense on the basis of the abstract forms 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 (60), the first stem consonant appears to be a coronal obstruent. We have previously seen that when the stem-initial consonant is a coronal, obstruent vowel harmony is undone (ní-tlob ‘I pray’), so (60) is exceptional on the surface. In addition, the prefix vowel is unexpectedly long, whereas otherwise it has always been short.

(60) nóodos  ‘I dive’  tóodos  ‘you dive’
    nóod’ob  ‘I please’  tóod’ob  ‘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, dʒ, t, but the abstract consonant ʕ, thus ʕdós/, ʔdʒob/, ʔtor/: ʕ is not a coronal obstruent, so it does not cause fronting of the prefix vowel.

Other examples provide crucial evidence regarding the nature of this abstract consonant. The data in (61) show a lengthened prefix vowel, which argues that the stems underlingly have the initial abstract consonant that deletes and causes vowel lengthening: [náalaʔ] comes from ʔni-ʕlaʔ/.

(61) náalaʔ  ‘I close’  táalaʔ  ‘you close’
    náasar  ‘I squeeze’  táasar  ‘you squeeze’
    náaraʃ  ‘I tickle’  táaraʃ  ‘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 as we have hypothesized, 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 (62) show examples of verbs whose true underlying imperfective stems are CCV.

(62) náʔ-ra  ‘I read’  náʔ-ra-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 /ś/. The singular columns do not have any striking irregularities which distinguish them from true CVCV stems.
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 with a medial sonorant, which would not exist in hypothetical *[níblau]. This is explained if the stem ends with /ʕ/. Thus /ni-smiʕ-u/ should surface as nisímʕu, by analogy to /ni-tlob-u/ → [nitólbu] ‘we ask.’ The consonant /ʕ/ induces lowering of the vowel i, and ʕ itself becomes a, 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 (64) show, stems ending in the consonant /ʕ/ realize that consonant as [ʔ] after long high vowels.

<table>
<thead>
<tr>
<th>Verb</th>
<th>Participle</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>ní-sma</td>
<td>‘I hear’</td>
<td>ni-síma-w ‘we hear’</td>
</tr>
<tr>
<td>ní-zra</td>
<td>‘I sow’</td>
<td>ni-zíra-w ‘we sow’</td>
</tr>
<tr>
<td>ní-bla</td>
<td>‘I swallow’</td>
<td>ni-bíla-w ‘we swallow’</td>
</tr>
<tr>
<td>náʔla</td>
<td>‘I earn’</td>
<td>naʔlwa ‘we earn’</td>
</tr>
</tbody>
</table>

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 (64). Although the forms of the participials [ʔiiː] and [ʔiiː] are analogous, we can tell from the inflected forms [fétah] ‘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 [ʔ], 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 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 /o/ in Hungarian, or deriving [ɔ] from /œ̆/ 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.

### 8.4 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 evidence that abstract analyses can be psychologically
valid, analogous to the historical arguments which Kiparsky adduced from the history of Yiddish and other languages in support of the more surface-oriented approach to phonology.

8.4.1 Abstract analysis and historical change: Tera

One such argument for the psychological reality of abstract analysis comes from Tera. Newman 1968 provides a synchronic and diachronic argument for abstract phonology, where similar surface forms have different underlying forms.

The synchronic argument. Data in (65) illustrate a basic alternation. Some nouns ending in [i] in their citation forms lack that vowel in phrase medial contexts:

(65) na sedi ‘this is a snake’ na sedi a ‘this is not a snake’
     na debi ‘this is gum’  na debi a ‘this is not gum’
     dala wa wudi ‘Dala pointed’
     dala wa wudi koro ‘Dala pointed at the donkey’
     dala wa mbuki ‘Dala threw’
     dala wa mbuki koro ‘Dala threw at the donkey’

Not all words ending in [i] prepausally engage in this alternation, as the data in (66) demonstrate:

(66) na wudi ‘this is milk’  na wudi a ‘this is not milk’
     a sabi ‘this is a stick’  a sabi a ‘this is not a stick’

Given a vowel ~ Ø alternation plus a set of stems which are invariantly i-final in (66), we might be led to surmise that the stems in (65) are C-final, and take an epenthetic vowel [i] phrase-finally. This can be ruled out given (67), where the stem ends in a consonant both phrase-medially and phrasefinally.

(67) na ruf ‘this is a baboon’  na ruf a ‘this is not a baboon’
     tin zof ‘she is a slob’  tin zof a ‘she is not a slob’
     na boj ‘this is white’  na boj a ‘this is not white’

A completely surface-oriented account where the underlying form must be one of the surface variants is untenable: the nouns in (65) have a variant with the vowel [i], but selecting /i/ for the underlying form fails to distinguish (65) from (66) which always have [i]; and the nouns of (65) also have a variant with no final vowel, but the nouns in (67) always lack a final vowel.
Other roots of the variable-final type give evidence that the problematic stems in (65) underlyingly end in schwa. The data in (68) provide monosyllabic words which have the shape Ci prepausally and Cə phrase medially.

(68)  dala wa ɓi     ‘Dala received’
        dala wa ɓə 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.

(69)  dala wa ɓi     ‘Dala paid’
        dala wa ɓi sule ‘Dala paid a shilling’
        dala wa ɓi     ‘Dala roasted’
        dala wa ɓi ɬu  ‘Dala roasted meat’

For the stems in (68), an obvious nonabstract solution is available: the stems end with /ə/, and there is a rule turning schwa into [i] prepausally:

(70)  ə → i  / _ #

This applies in dala wa ɗi ‘Dala went’ from dala wa ɗə, but final schwa is unaffected in dala wa ɗə goma ‘Dala went to the market.’ The stems in (69) 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.

There are other stems with final [i] prepausally and [ə] phrase medially.

(71)  na parsı     ‘this is a horse’
        na parsə ɓa  ‘this is not a horse’
        dala wa kədi ‘Dala pulled’
        dala wa kədə koro ‘Dala pulled a donkey’

These stems 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:

<table>
<thead>
<tr>
<th>Stem shape</th>
<th>Medial</th>
<th>Prepausal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cə</td>
<td>Cə</td>
<td>Ci</td>
</tr>
<tr>
<td>CVCCə</td>
<td>CVCCə</td>
<td>CVCCI</td>
</tr>
<tr>
<td>CVZə</td>
<td>CVZə</td>
<td>CVZi</td>
</tr>
<tr>
<td>CVCə</td>
<td>CVC</td>
<td>CVCi</td>
</tr>
</tbody>
</table>

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 debi ~ deb with a single voiceless consonant before
final schwa, the analysis is abstract because schwa is never phonetically manifested in the morpheme. 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 that deletes word-final phrase-medial schwa providing the stem is polysyllabic and ends only in a single voiceless consonant.

\[(73) \ o \rightarrow \emptyset / V \quad C \quad _\# \ldots \quad [- \text{voice}]\]

More evidence supports abstract schwa in certain words. The examples in (74a) show that when a vowel -a marking definite nouns is suffixed to a stem such as /pars/ which ends in schwa, schwa deletes, whereas underlying /i/ is not deleted. The data in (74b) show the same thing with the imperative suffix /u/:

\[\begin{align*}
(74) \ a. \ & \text{parsi} \leftarrow /\text{pars}/ & \text{‘horse’} & \text{pars-a} & \text{‘the horse’} \\
& \text{wudi} & \text{‘milk’} & \text{wudi-a} & \text{‘the milk’} \\
\text{b.} \ & \text{vi} & \text{‘to roast’} & \text{vi-u} & \text{‘roast!’} \\
& \text{di} \leftarrow /\text{di}/ & \text{‘to go’} & \text{di-u} & \text{‘go!’} \\
& \text{kadi} \leftarrow /\text{kadi}/ & \text{‘to pull’} & \text{kad-u} & \text{‘pull!’} \\
& \text{mbuki} \leftarrow /\text{mbuki}/ & \text{‘to throw’} & \text{mbuk-u} & \text{‘throw!’} \\
\end{align*}\]

This motivates a rule of prevocalic schwa deletion, which provides another diagnostic that differentiates schwa from /i/.

\[(75) \ o \rightarrow \emptyset / _\quad V\]

Although ‘throw’ only has the surface variants [mbuki] ~ [mbuk], it behaves exactly like stems such as /kadi/ 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 (sabir tada-kandi ‘heavy stick’) and as -ndi when the stem ends in a consonant (sabir teber-ndi ‘straight stick’). The stem of the word for ‘long’ ends in abstract schwa, since it alternates between final [i] (sabira kori ‘the stick is long’) and medial Ø (sabira kor ba ‘the stick is not long’). Furthermore, the stem selects the postvocalic variant of the adjective suffix (sabir kor-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. Thus multiple lines of argument establish the presence of an abstract vowel schwa in a number of words in the synchronic grammar of Tera.

**The diachronic argument.** A recent sound change in Tera provides a grammar-external test of the abstract hypothesis. In one dialect of Tera, spoken in the town of Zambuk, a rule was added which palatalized \(t, d\) and
d' to t', d² and d³ before i. The dialect of Tera, spoken in Wuyo, is representa-
tive of the rest of Tera, in retaining the original alveolars. Thus we find Wuyo da, Zambuk da ‘one’ with no palatalization, but Wuyo dʒ, Zambuk dʒi ‘to get up’ where d palatalizes. 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, xat-ən. In Wuyo one finds wudi ‘milk’ and in Zambuk one finds wudʒi, deriving from /wuɗi/ – that the final vowel is /i/ and not /əl/ is shown by the phrase medial form wudi.

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, kədi medially (cf. dala wa kədi koro ‘Dala pulled a donkey’), and therefore we know that the stem is /kədi/. In the Zambuk dialect, the medial form is also kədi, showing that the stem ends 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 /wudədi/ ‘to point’ which appears in the Wuyo dialect as wudi prepausally and as wudə medially (dala wa wudə koro ‘Dala pointed at a donkey’) appears as wudi in the Zambuk dialect, without palatalization, as is regularly the case with the vowel [i] derived from /əl/. The fact that the innovative sound change of palatalization found in the Zambuk dialect is sensitive to the sometimes abstract distinction between underlying /i/ versus ones derived from schwas, especially when the schwa never surfaces, supports the claim that abstract underlying forms can be psychologically real.

### 8.4.2 Abstract reanalysis in Matuumbi NC sequences

Other evidence for abstract phonology comes from a historical reanalysis of postnasal consonants in the Bantu language Matuumbi. Nouns in Bantu are composed of a prefix plus stem, and the prefix changes between singular and plural. For example, proto-Bantu 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 linguistics, reconstructed forms are marked with an asterisk).

<table>
<thead>
<tr>
<th></th>
<th>Proto-Bantu sg</th>
<th>Class</th>
<th>Proto-Bantu pl</th>
<th>Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>*mo-nto</td>
<td>1</td>
<td>'ba-ntu</td>
<td>2</td>
<td>‘person’</td>
</tr>
<tr>
<td>*mo-gonda</td>
<td>3</td>
<td>'m-gonda</td>
<td>4</td>
<td>‘field’</td>
</tr>
<tr>
<td>*li-tako</td>
<td>5</td>
<td>'ma-tako</td>
<td>6</td>
<td>‘buttock’</td>
</tr>
<tr>
<td>*m-paka</td>
<td>9</td>
<td>'dim-paka</td>
<td>10</td>
<td>‘cat’</td>
</tr>
<tr>
<td>*lo-badu</td>
<td>11</td>
<td>‘dim-badu</td>
<td>10</td>
<td>‘rib’</td>
</tr>
</tbody>
</table>
A postnasal voicing rule was added in the proto-Rufiji-Ruvuma subgroup of Bantu (a subgroup which includes Matuumbi), so that original *mpaka ‘cat’ came to be pronounced mbaka in this subgroup.

(77)  
<table>
<thead>
<tr>
<th>Proto-Bantu</th>
<th>Matuumbi</th>
</tr>
</thead>
<tbody>
<tr>
<td>*mpaka</td>
<td>mbaka</td>
</tr>
<tr>
<td>*ŋkaŋga</td>
<td>ŋgaanga</td>
</tr>
<tr>
<td>*ntembo</td>
<td>ndeembo</td>
</tr>
<tr>
<td>*monto</td>
<td>muundu</td>
</tr>
<tr>
<td>*ŋkongoni</td>
<td>ŋguuŋuni</td>
</tr>
<tr>
<td>cf. *mbabada</td>
<td>mbabala</td>
</tr>
<tr>
<td>*mbodi</td>
<td>mbwi</td>
</tr>
<tr>
<td>*mboa</td>
<td>mbwa</td>
</tr>
</tbody>
</table>

Another inconsequential change 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 Matuumbi, 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 surface [mbwa] ‘dog’ (proto-Bantu *m-boa) originally in classes 9–10, the concrete analysis is that the underlying form in proto-Rufiji is /m-bwal/. It was always pronounced as [mbwa], since the root was always preceded by a nasal prefix. The absence of alternations in the phonetic realization of the initial consonant would give reason to think that phonetic [b] derives from underlying /bl/. By the same reasoning, we predict that earlier mpaka ‘cat’ is reanalyzed as /b/, once the word came to be pronounced as mbaka in all contexts: compare Yiddish gelt.  

The restructuring of the morphological system of Nkongo Matuumbi where 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 forms; the plural has the prefix ma-. As the following data show, the concrete approach is wrong.

(78)  
<table>
<thead>
<tr>
<th>Proto-Bantu</th>
<th>Matuumbi sg</th>
<th>Original pl</th>
<th>Innovative pl</th>
</tr>
</thead>
<tbody>
<tr>
<td>*m-pembe</td>
<td>m-beembe</td>
<td>m-beembe</td>
<td>ma-peembe</td>
</tr>
<tr>
<td>*ŋ-koko</td>
<td>ŋ-guku</td>
<td>ŋ-goko</td>
<td>ma-kuku</td>
</tr>
<tr>
<td>*m-boa</td>
<td>m-bwa</td>
<td>m-bwa</td>
<td>ma-pwa</td>
</tr>
<tr>
<td>*m-babada</td>
<td>m-babala</td>
<td>m-babala</td>
<td>ma-pabala</td>
</tr>
<tr>
<td>*m-bodi</td>
<td>m-bwi</td>
<td>m-bwi</td>
<td>ma-pwi</td>
</tr>
<tr>
<td>*m-bango</td>
<td>m-baango</td>
<td>m-baango</td>
<td>ma-paango</td>
</tr>
<tr>
<td>*m-botoka</td>
<td>m-botoka</td>
<td>m-botoka</td>
<td>ma-potoka</td>
</tr>
</tbody>
</table>

While the distinction /mp/ ~ /mb/ was neutralized, it was neutralized in favor of a phonetically more abstract consonant /p/ rather than the concrete consonant /bl/.
This reanalysis did not affect all nouns which had a singular or plural in classes 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.

(79) | Proto-Bantu | Matuumbi sg | Matuumbi pl |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>*m-badu</td>
<td>lu-bau</td>
<td>m-bau</td>
</tr>
<tr>
<td>*n-godi</td>
<td>lu-goi</td>
<td>η-goi</td>
</tr>
<tr>
<td>*n-dimi</td>
<td>lu-dimi</td>
<td>n-dimi</td>
</tr>
<tr>
<td>*ŋ-kongoŋi</td>
<td>lu-kuunguni</td>
<td>η-guunguni</td>
</tr>
<tr>
<td>*n-tondua</td>
<td>lu-toondwa</td>
<td>n-doondwa</td>
</tr>
</tbody>
</table>

A word such as ‘rib’ always had a morphological variant 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 – 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 reanalyzed 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 where 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 in assuming underlying /aveg/, from the perspective of markedness or phonetic conservatism.

### 8.4.3 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 in the language, games 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 (1981). A number of verbs have the underlying form /CaCaCi, but this analysis is abstract in that, for these
verbs, the first vowel sequence is never found on the surface, and the root surfaces as [CiCaC].

8.4.3.1 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 replacing all underlying vowels with /i/. Underlying /i/ deletes in an open syllable, as shown by the following data:

(80) 3sg masc 3sg fem 1sg
hzim  hizm-at  hzim-t  ‘be tied’
hfir  hifr-at  hfir-t  ‘be dug’
ʃɾib  ʃɾib-at  ʃɾib-t  ‘be drunk’
ʕzim  ʕizm-at  ʕzim-t  ‘be invited’
lbis  libs-at  libis-t  ‘be worn’

Taking underlying /hizim/ and /hizim-t/ as examples, the vowel /i/ in the first syllable is in an open syllable, so the rule of high-vowel deletion applies, giving [hzim] and [hzimt]. In the case of /hizim-at/, both vowels i are in an open syllable: the second i deletes, which makes the first syllable closed, so the first vowel does not delete, resulting in [hzimat]. The following rule is motivated by (80).

(81)  i → Ø /_ CV  High-vowel deletion

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 (82):

(82) 3sg masc 3sg fem 1sg
simis  simis-at  simis-t  ‘hear’
libis  labis-at  libis-t  ‘wear’
ʃɾib  ʃɾib-at  ʃɾib-t  ‘drink’
jibis  jibs-at  jibs-t  ‘become dry’
silim  salm-at  silim-t  ‘save’
lisib  labis-at  lisib-t  ‘play’
hilim  halm-at  hilim-t  ‘dream’

In underlying /simis-at/, the vowel /i/ is in an open syllable so it deletes, giving [simsat]. In /simis/ and /simis-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:

(83)  a → i /_ Ci
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 is how it surfaces.

(84) 3sg masc | 3sg fem | 1sg
    gaʕad | gʕad-at | gaʕad-t | ‘sit’
    waʕad | wʕad-at | waʕad-t | ‘promise’
    tʕaʕan | tʕan-at | tʕaʕan-t | ‘stab’
    sahah | sh-b-at | sahah-t | ‘pull’
    tʕaʕan | tʕan-at | tʕaʕan-t | ‘grind’
    daxal | dxal-at | daxal-t | ‘enter’
    naxal | naxal-at | naxal-t | ‘sift’

Examples such as [gʕad-at] from /gaʕad-at/ illustrate the application of another rule, one deleting /a/ when followed by CVCV.

(85) a → Ø / _ CVCV

An important fact about the stems in (84) is that the second consonant is a guttural (x, y, h, h, i or j). 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 vowel can undergo the dissimilative raising rule. Now consider the data in (86), where the first consonant is a guttural but the second is not.

(86) 3sg masc | 3sg fem | 1sg
    ʕazam | ʕzim-at | ʕazam-t | ‘invite’
    hazah | ẖzim-at | hazam-t | ‘tie’
    hakam | ẖkim-at | hakam-t | ‘rule’

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 debate.

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 [ʕzim-at] (with deletion of the first vowel by (85)). This rule is separate from the harmony rule that turns /a/ into [i] before [i], because harmony applies irrespective of the flanking consonants, cf. [ẖilim] ‘he dreamt.’

(87) a → i / _ C a  (target is not adjacent to a guttural consonant)

In [ʕazam] and [ʕazam-t], there is no dissimilation because the first consonant is guttural, which prevents the following /a/ from undergoing dissimilation.
Examples in (88) show the same restriction on dissimilation of the second vowel /a/, which does not become [i] when the last consonant is a guttural.

\[
\begin{array}{ccc}
3\text{sg masc} & 3\text{sg fem} & 1\text{sg} \\
\text{difaš} & \text{dfaš-at} & \text{ɗaš-t} & \text{‘push’} \\
\text{rɪkaš} & \text{rɪkaš-at} & \text{rɪkaš-t} & \text{‘bend’} \\
\text{xdaʃ} & \text{xdaʃ-at} & \text{xdaʃ-t} & \text{‘cheat’}
\end{array}
\]

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 (89), the first vowel is prevented from dissimilating because it is preceded by a guttural. In addition, the second stem vowel is prevented from dissimilating because it is separated from suffixal /a/ by a coronal sonorant. Therefore, both underlying stem vowels remain unchanged.

\[
\begin{array}{ccc}
3\text{sg masc} & 3\text{sg fem} & 1\text{sg} \\
\text{hafar} & \text{hfar-at} & \text{hafar-t} & \text{‘dig’} \\
\text{hamal} & \text{hmal-at} & \text{hamal-t} & \text{‘carry’} \\
\text{γasal} & \text{γas-al-t} & \text{γasal-t} & \text{‘wash’}
\end{array}
\]

In the examples of (90), the first vowel is followed by a consonant other than a coronal sonorant, and is neither preceded nor followed by a guttural, so it dissimilates to [i]. The second vowel is followed by a coronal sonorant, so there is no dissimilation in the second syllable.

\[
\begin{array}{ccc}
3\text{sg masc} & 3\text{sg fem} & 1\text{sg} \\
\text{nizal} & \text{nizal-at} & \text{nizal-t} & \text{‘get down’} \\
\text{sikan} & \text{sikan-t} & \text{sikan-t} & \text{‘occupy’} \\
\text{kisar} & \text{kisar-at} & \text{kisar-t} & \text{‘break’} \\
\text{dfan} & \text{dfan-t} & \text{dfan-t} & \text{‘bury’} \\
\text{nital} & \text{nital-t} & \text{nital-t} & \text{‘steal’} \\
\text{ʃitar} & \text{ʃtar-at} & \text{ʃtar-t} & \text{‘divide’}
\end{array}
\]

In (91) 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 nor 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.

\[
\begin{array}{ccc}
3\text{sg masc} & 3\text{sg fem} & 1\text{sg} \\
\text{dʒalas} & \text{dʒlis-at} & \text{dʒalas-t} & \text{‘sit’} \\
\text{garas} & \text{gar-as-t} & \text{gar-as-t} & \text{‘sting’} \\
\text{garat} & \text{gar-at-t} & \text{gar-at-t} & \text{‘throw’} \\
\text{sarag} & \text{srig-at} & \text{srig-t} & \text{‘steal’} \\
\text{balas} & \text{blis-at} & \text{blas-t} & \text{‘denounce’} \\
\text{ʃanag} & \text{ʃnig-at} & \text{ʃanag-t} & \text{‘hang’} \\
\text{daras} & \text{dris-at} & \text{daras-t} & \text{‘study’}
\end{array}
\]
Finally, verbs with no gutturals or coronal sonorants are given in (92).

(92)  
<table>
<thead>
<tr>
<th>3sg masc</th>
<th>3sg fem</th>
<th>1sg</th>
</tr>
</thead>
<tbody>
<tr>
<td>kitab</td>
<td>ktib-at</td>
<td>kitab-t</td>
</tr>
<tr>
<td>misak</td>
<td>msik-at</td>
<td>misak-t</td>
</tr>
<tr>
<td>sikat</td>
<td>skit-at</td>
<td>sikat-t</td>
</tr>
<tr>
<td>nitaf</td>
<td>ntif-at</td>
<td>nitaf-t</td>
</tr>
<tr>
<td>gisam</td>
<td>gsim-at</td>
<td>gisam-t</td>
</tr>
<tr>
<td>giəab</td>
<td>gəib-at</td>
<td>giəab-t</td>
</tr>
<tr>
<td>nkas</td>
<td>nkis-at</td>
<td>nkas-t</td>
</tr>
</tbody>
</table>

‘write’ ‘catch’  ‘stop talking’  ‘pluck’  ‘divide’  ‘catch’  ‘retain’

By the deletion rule (85), 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 vowel /a/ in the second syllable of verbs like [kitab] is only mildly abstract, since it does surface as [a] as long as the syllable is not open. The initial /a/, the syllable on the other hand, is fully 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 initial nondeleting [i] in an open syllable is entirely predictable. It appears when neither the first nor second stem consonant is a guttural, and when the second stem consonant is not a coronal sonorant. This nondeleting [a] is thus in complementary distribution with surface [a] (which nonabstractly 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.

### 8.4.3.2 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 verb forms hazam ‘he tied’ and hzim-at ‘she tied.’ In hazam, the first vowel does not dissimilate because of the preceding guttural; in hzimat the second stem vowel dissimilates because it is neither preceded nor followed by a guttural, and it is not followed by a coronal sonorant.

(93)  
<table>
<thead>
<tr>
<th>‘he tied’</th>
<th>‘she tied’</th>
</tr>
</thead>
<tbody>
<tr>
<td>hamaz</td>
<td>hmižat</td>
</tr>
<tr>
<td>zaham</td>
<td>zhamat</td>
</tr>
<tr>
<td>zimah</td>
<td>zmahat</td>
</tr>
</tbody>
</table>
In the permuted forms *hamaz* and *hmizat*, 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 *zimah ~ zmahat*. 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 *zaham ~ zhamat*, 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 [difəʕ]. Such a supposed underlying representation is abstract, since the vowel of the first syllable always surfaces as [i] or Ø, cf. *difəʕ* ‘he pushed,’ *dfsafat* ‘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 to be [a].

(94)  ‘he pushed’        ‘she pushed’
      ᵛdfaʕ        ᵛdfsafat
      ᵝdafaʕ        ᵝdfsafat
      ᵝafaʕ        ᵝdfsafat
      ᵝafaḍ        ᵝdfsafat

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/.

### 8.5 How abstract is phonology?

On the one hand we have argued for abstract analyses of Matuumbi, Yawelmani, Maltese, and other languages; but we have argued against abstract analyses of English. The reason for this apparently inconsistent view of abstractness is that abstractness per se is not the issue; the proper question to be focusing on is what motivates an analysis. Thus we conclude that the formal theory of grammar imposes no constraints on the relation between underlying and surface forms, though the theory does state what kinds of elements can exist in underlying representations: phonetically interpretable combinations of features, i.e. segments.

This does not mean that highly abstract underlying representations can be gratuitously assumed. Underlying representations require
motivation: 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 are identical. The question that needs further investigation is, what constitutes valid “evidence to the contrary”? 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 larger question which this debate 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 actually pronounced in the language. We cannot show that these claims are literally “wrong”: what we can do is show that such a position renders us incapable of capturing 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 one’s own discipline. Finally the evidence must be interpreted against a general theory of, for example, 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. Nouns in Slovak come in three genders, which determine what suffix if any is used in the nominative singular: masculines have no suffix, feminines have -a, and neuters have -o.
A. There is a process of lengthening which takes place in certain morphological contexts, including the genitive plural and the diminutive.

<table>
<thead>
<tr>
<th>Nom sg</th>
<th>Gen pl</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>lipa</td>
<td>lipa</td>
<td>‘linden tree’</td>
</tr>
<tr>
<td>muxa</td>
<td>muxa</td>
<td>‘fly’</td>
</tr>
<tr>
<td>lopata</td>
<td>lopata</td>
<td>‘shovel’</td>
</tr>
<tr>
<td>srmn</td>
<td>srmn</td>
<td>‘deer’</td>
</tr>
<tr>
<td>ziena</td>
<td>ziena</td>
<td>‘woman’</td>
</tr>
<tr>
<td>kazeta</td>
<td>kazeta</td>
<td>‘box’</td>
</tr>
<tr>
<td>hora</td>
<td>hora</td>
<td>‘forest’</td>
</tr>
<tr>
<td>sirota</td>
<td>sirota</td>
<td>‘orphan’</td>
</tr>
<tr>
<td>paeta</td>
<td>piat</td>
<td>‘heel’</td>
</tr>
<tr>
<td>mtaeta</td>
<td>miat</td>
<td>‘mint’</td>
</tr>
<tr>
<td>kopito</td>
<td>kopito</td>
<td>‘hoof’</td>
</tr>
<tr>
<td>bruxo</td>
<td>bruxo</td>
<td>‘belly’</td>
</tr>
<tr>
<td>blato</td>
<td>blato</td>
<td>‘mud’</td>
</tr>
<tr>
<td>salto</td>
<td>salto</td>
<td>‘somersault’</td>
</tr>
<tr>
<td>embargo</td>
<td>embargo</td>
<td></td>
</tr>
<tr>
<td>jabiko</td>
<td>jab</td>
<td>k</td>
</tr>
<tr>
<td>koleso</td>
<td>koleso</td>
<td>‘wheel’</td>
</tr>
<tr>
<td>lono</td>
<td>lono</td>
<td>‘lap’</td>
</tr>
<tr>
<td>hovaedo</td>
<td>hovaedo</td>
<td>‘government’</td>
</tr>
<tr>
<td>vla:da</td>
<td>vla:da</td>
<td>‘blouse’</td>
</tr>
<tr>
<td>dla:to</td>
<td>dla:to</td>
<td>‘chisel’</td>
</tr>
<tr>
<td>vino</td>
<td>vino</td>
<td>‘vine’</td>
</tr>
<tr>
<td>tʃiar</td>
<td>tʃiar</td>
<td>‘line’</td>
</tr>
<tr>
<td>hniezdo</td>
<td>hniezdo</td>
<td>‘nest’</td>
</tr>
</tbody>
</table>

B. There is also a shortening rule that applies in certain morphological contexts, including the imperfective of verbs and the comparative of adjectives.

<table>
<thead>
<tr>
<th>Perfective</th>
<th>Imperfective</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>odli:sitl</td>
<td>odlisovatl</td>
<td>‘to distinguish’</td>
</tr>
<tr>
<td>kup:itl</td>
<td>kupovatl</td>
<td>‘to buy’</td>
</tr>
<tr>
<td>ohla:sitl</td>
<td>ohlasovatl</td>
<td>‘to announce’</td>
</tr>
<tr>
<td>predl:ʒil</td>
<td>predljzovatl</td>
<td>‘to extend’</td>
</tr>
<tr>
<td>oblietatl</td>
<td>obletovatl</td>
<td>‘to fly around’</td>
</tr>
<tr>
<td>uviazatl</td>
<td>uvæzovatl</td>
<td>‘to bind’</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Adjective</th>
<th>Comparative</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>bli:ski</td>
<td>bli:ʃi:</td>
<td>‘near’</td>
</tr>
<tr>
<td>u:ski</td>
<td>u:ʃi:</td>
<td>‘narrow’</td>
</tr>
<tr>
<td>kratki</td>
<td>kratʃi:</td>
<td>‘short’</td>
</tr>
<tr>
<td>bieli</td>
<td>belʃi:</td>
<td>‘white’</td>
</tr>
<tr>
<td>rietki</td>
<td>reʃi:</td>
<td>‘rare’</td>
</tr>
</tbody>
</table>
C. There is an alternation in the form of case suffixes which is governed by properties of the stem which precedes.

<table>
<thead>
<tr>
<th>Nom sg</th>
<th>Gen sg</th>
<th>Nom pl</th>
<th>Dat pl</th>
<th>Loc pl</th>
</tr>
</thead>
<tbody>
<tr>
<td>mesto</td>
<td>mesta</td>
<td>mesta:</td>
<td>mesta:m</td>
<td>mesta:x</td>
</tr>
<tr>
<td>blato</td>
<td>blata</td>
<td>blata:</td>
<td>blata:m</td>
<td>blata:x</td>
</tr>
<tr>
<td>hovæda</td>
<td>hovæda</td>
<td>hovæda:</td>
<td>hovæda:m</td>
<td>hovæda:x</td>
</tr>
<tr>
<td>dla:to</td>
<td>dla:ta</td>
<td>dla:ta:</td>
<td>dla:ta:m</td>
<td>dla:tax</td>
</tr>
<tr>
<td>vi:no</td>
<td>vi:na</td>
<td>vi:na:</td>
<td>vi:nam</td>
<td>vi:nax</td>
</tr>
<tr>
<td>hniezdo</td>
<td>hniezda</td>
<td>hniezda:</td>
<td>hniezdam</td>
<td>hniezdax</td>
</tr>
</tbody>
</table>

D. The rule that explains the alternations in C also explains why a rule motivated by the data in A seems not to have applied.

<table>
<thead>
<tr>
<th>Nom sg</th>
<th>Gen pl</th>
</tr>
</thead>
<tbody>
<tr>
<td>za:hrada</td>
<td>za:hrad</td>
</tr>
<tr>
<td>ni:ʒina</td>
<td>ni:ʒin</td>
</tr>
<tr>
<td>za:toka</td>
<td>za:tok</td>
</tr>
<tr>
<td>pi:smeno</td>
<td>pi:smen</td>
</tr>
<tr>
<td>za:meno</td>
<td>za:men</td>
</tr>
<tr>
<td>lietːfo</td>
<td>lietːfiv</td>
</tr>
</tbody>
</table>

E. Some stems underlyingly end with consonant clusters, and undergo a process of vowel epenthesis that eliminates certain kinds of consonant clusters.

<table>
<thead>
<tr>
<th>Nom sg</th>
<th>Gen pl</th>
</tr>
</thead>
<tbody>
<tr>
<td>ikrá</td>
<td>ikier</td>
</tr>
<tr>
<td>ihła</td>
<td>ihiel</td>
</tr>
<tr>
<td>dogma</td>
<td>dogiem</td>
</tr>
<tr>
<td>sosna</td>
<td>sosien</td>
</tr>
<tr>
<td>bedro</td>
<td>bedier</td>
</tr>
<tr>
<td>radiol</td>
<td>radiel</td>
</tr>
<tr>
<td>hradba</td>
<td>hradieb</td>
</tr>
<tr>
<td>doska</td>
<td>dosiek</td>
</tr>
<tr>
<td>krí:dlo</td>
<td>krí:del</td>
</tr>
<tr>
<td>tliː:sl</td>
<td>tliː:sel</td>
</tr>
<tr>
<td>pasmo</td>
<td>pasem</td>
</tr>
<tr>
<td>vla:kno</td>
<td>vlaken</td>
</tr>
<tr>
<td>plat:no</td>
<td>plat:ten</td>
</tr>
</tbody>
</table>

Urhobo

Account for the phonological alternations in the following data. Tone can be ignored. The diacritic underneath a vowel indicates that the vowel is [+ATR] (“Advanced Tongue Root”), and vowels without the diacritic are [−ATR].

<table>
<thead>
<tr>
<th>ur</th>
<th>ū</th>
<th>ɾu</th>
<th>sjo</th>
<th>kwo</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘pull’</td>
<td>‘to pull’</td>
<td>‘rope’</td>
<td>‘pull a rope’</td>
<td>‘to pull’</td>
</tr>
<tr>
<td>‘spray’</td>
<td>‘to spray’</td>
<td>‘clothes’</td>
<td>‘spray clothes’</td>
<td></td>
</tr>
<tr>
<td>‘pour’</td>
<td>‘to pour’</td>
<td>‘oil’</td>
<td>‘oil’</td>
<td>‘pour oil’</td>
</tr>
</tbody>
</table>
rú ‘do’ èrwo ‘to do’ èzèkè ‘dedication’ nw èzèkè ‘do a dedication’
sè ‘call’ èsè ‘to call’ ojäré ‘man’ s ojäré ‘call a man’
mè ‘plait’ èmè ‘to plait’ écò ‘hair’ m écò ‘plait hair’
cò ‘steal’ ècò ‘to steal’ èkpù ‘bag’ c èkpù ‘steal a bag’
φè ‘urinate’ èpè ‘to urinate’ ègò ‘bottle’ φ ègò ‘fill a bottle’
jè ‘sell’ ètè ‘to sell’ èyìmá ‘clothes’ jèyìmá ‘sell clothes’
hwè ‘laugh’ èhwè ‘to laugh’ òmò ‘child’ hw òmò ‘laugh at a child’
vè ‘expose’ èvé ‘to expose’ v òmò ‘expose a child’
gbè ‘clear’ ègbè ‘to clear’ áyìwá ‘forest’ gb áyìwá ‘clear a forest’
tè ‘be worthless’ ètè ‘to be worthless’
kò ‘plant’ èkò ‘to plant’ jìbò ‘pepper’ k jìbò ‘plant pepper’
γò ‘worship’ èyò ‘to worship’ jì ‘elephant’ γ jì ‘worship elephant’
sà ‘shoot’ èsà ‘to shoot’ óìhwò ‘person’ s óìhwò ‘shoot a person’
hwà ‘pay’ èhwà ‘to pay’ hw óìhwò ‘pay a person’
γè ‘be foolish’ èyè ‘to be foolish’
φè ‘be wide’ èφè ‘to be wide’
βè ‘bear’ èβè ‘to bear’ òmò ‘child’ òjò òmò ‘bear a child’
rè ‘eat’ èrjò ‘to eat’ ónè ‘yam’ ri ónè ‘eat yam’
sè ‘reject’ èsjò ‘to reject’ èfè ‘wealth’ sj èfè ‘reject wealth’
cò ‘trade’ èçwò ‘to trade’ èrè ‘mat’ çw èrè ‘trade a mat’
sò ‘sing’ èswò ‘to sing’ ùnè ‘song’ sw ùnè ‘sing a song’

* “spray” refers to lavish gift-giving.
Abstractness and psychological reality

Further reading
Chomsky and Halle 1968; Hudson 1974; Hyman 1970; Kiparsky 1968b; Sapir 1933.
This final chapter introduces an alternative model of how sounds are represented, the nonlinear theory. 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.

**KEY TERMS**
- autosegmental phonology
- tone stability
- floating tone
- across-the-board effects
- feature geometry
- syllable
The theoretical model we have been assuming—known as the linear theory of representation—was quite successful in explaining a number of facts about sound systems. An essential characteristic of the theory is that segments are matrices of feature values, where every segment has a specification for each of the two dozen distinctive features. There was one phonological realm which the theory had largely ignored, and that was tone, and that had significant repercussions.

9.1 The autosegmental theory of tone: the beginnings of a change

There were a few proposals regarding tone features, but they did not reach the degree of acceptance that those for other features reached. One of the primary problems regarding tone was how to represent contour tones such as rising and falling.

9.1.1 The problem of contours

One possibility is that contour tones are simply H (high) or L (low) 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.

\[
\begin{align*}
H &= \begin{bmatrix} +H \\ -\text{contour} \end{bmatrix} \\
R &= \begin{bmatrix} -H \\ +\text{contour} \end{bmatrix} \\
L &= \begin{bmatrix} -H \\ -\text{contour} \end{bmatrix} \\
F &= \begin{bmatrix} +H \\ +\text{contour} \end{bmatrix}
\end{align*}
\]

Such a theory is ultimately insufficient 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 a theory of features is how it accounts for phonological processes. This theory of tone makes predictions: it predicts that R and F will be a natural class because they are [+contour], 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 notably Hyman and Schuh 1974. Such research has shown that the following are fairly common tonal processes.

\[
\begin{align*}
(2) \quad a. \quad H &\rightarrow R\{L,F\}_- \\
b. \quad L &\rightarrow F\{H,R\}_- \\
c. \quad H &\rightarrow F\{L,R\}_- \\
d. \quad L &\rightarrow R\{H,F\}_-
\end{align*}
\]
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] \rightarrow [+\text{contour}] / [-H]\]
    d. \([-H] \rightarrow [+\text{contour}] / [+H]\]

However, the first two processes cannot be formalized, since \([L,F] \) or \([H,R] \) are not a definable class using this theory. \(L \) tone is, \textit{ex hypothesi}, \([-H]\) whereas \(F\) is \([+H]\), so the class of progressive tone assimilations, one of the most common tone rules, is unformalizable.

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)  

Unlike the common rules in (2), such rules are totally nonexistent 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 an \(H\) 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. \([+H] \rightarrow [+\text{contour}] / [+H]\)  \quad (H \rightarrow F \mid \{L,R\})
    d. \([-H] \rightarrow [+\text{contour}] / [-H]\)  \quad (L \rightarrow R \mid \{H,F\})

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 \(R\) is simply a combination of an \(L\) followed by an \(H\), and \(F\) is a combination of an \(H\) followed by an \(L\); 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 Yekhee, illustrated below.

(6)  ídzé élà → ídzélà  \quad ‘three axes’
    èké élà → èkélà  \quad ‘three rams’
    údzé òkpá → údzıpá  \quad ‘one axe’
    òké òkpá → òkıpá  \quad ‘one ram’
    ówà ówà → ówówà  \quad ‘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.

\[
\begin{array}{c}
\text{+ syllabic} \\
\text{+ back} \\
\text{rd} \\
\text{H tone}
\end{array}
\begin{array}{c}
\text{+ syllabic} \\
\text{+ back} \\
\text{rd} \\
\text{H tone}
\end{array}
\]

The problem is short contour tones. A single vowel cannot be both –H tone and +H tone, and feature values cannot be ordered within a segment, but that is what is needed to represent short rising and falling tones.

### 9.1.2 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 at another level, with the two levels of representation being synchronized via association lines. This theory, known as autosegmental phonology, posited representations such as those in (8).

\[
\begin{array}{c}
\text{á} = \text{H} \\
\text{a} \\
\end{array}
\begin{array}{c}
\text{â} = \text{L} \\
\text{a} \\
\end{array}
\]

The representation of [á] simply says that when the rest of the vocal tract is in the configuration for the vowel [a], the vocal folds should be vibrating at a high rate as befits an H tone. The representation for [â] on the other hand says that while the rest of the vocal tract is producing the short vowel [a], the larynx should start vibrating slowly (produce an L tone), and then change to a higher rate of vibration to match that specified for an H tone – this produces the smooth increase in pitch which we hear as a rising tone. The representation of [á] 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).

\[
\begin{array}{c}
\text{H} \\
\text{V} \\
\end{array}
\begin{array}{c}
\text{L} \\
\text{V} \\
\end{array}
\begin{array}{c}
\text{H} \\
\text{V} \\
\end{array}
\begin{array}{c}
\text{L} \\
\text{V} \\
\end{array}
\]

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 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.”

\[(10) \begin{array}{c}
\text{L} \\
\text{H} \\
\text{V} \end{array} \begin{array}{c}
\vdash \\
\end{array} \begin{array}{c}
\text{V} \\
\end{array}\]

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:

\[(11) \begin{array}{c}
\text{H} \\
\vdash \\
\text{V} \\
\end{array}\]

Second, an element (tone or vowel) which has no corresponding association on the other tier (vowel or tone) is indicated with the mark \(\acute{\text{\texttt{'}}}\), thus \(\text{V}\ Arabia\) indicates a toneless vowel and \(\text{H}\ Arabia\) indicates an 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.

\[(12) \begin{array}{c}
\text{H} \text{ L} (=2b) \\
\vdash \\
\text{V} \text{ V} \\
\end{array} \begin{array}{c}
\text{H} \text{ L} (=2c) \\
\vdash \\
\text{V} \text{ V} \\
\end{array} \begin{array}{c}
\text{L} \text{ H} (=2d)) \\
\vdash \\
\text{V} \text{ V} \\
\end{array}\]

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 \{\text{L,F}\} and \{\text{H,R}\}, and if the conditioning tones stand on the right, then the natural groupings are \{\text{L,R}\} and \{\text{H,F}\}. In all other cases, the groupings of elements into natural classes are independent of whether the target is to the right or to 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 \(\text{H} \rightarrow \text{F} / \{\text{L,R}\} \) and \(\text{L} \rightarrow \text{R} / \{\text{H,F}\} \). The change of H to F after L would involve not just an adjustment in the temporal organization of an 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 formalizing such a rule in the autosegmental approach would be as in (13).
As we will discuss in this chapter, autosegmental theory resulted in a considerable reconceptualization of phonological processes, and the idea that rules should be stated as insertions and deletions of association relationships made it impossible to express certain kinds of arbitrary actions, such as that of (13).

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 with 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.

9.1.3 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 borne 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 an L vowel plus H vowel results in a rising-toned vowel, and H+L gives a falling-toned vowel.

(14) òké òkpá → òkõkpá  ‘one ram’
    ówà ówà → ówôwà  ‘every house’

In the autosegmental theory, deletion of a vowel does not directly affect the tone which was associated with it, and as a result, after deletion of the vowel the tone simply remains on the tonal tier with no association with the segmental tier – such an unassociated tone is referred to as a floating tone.

(15)  L H L H L H L H L H L
     |   |   |   |   |   |   |   |
     o k e o k p a → o k o k p 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 borne by some vowel – this condition is known as the Well-formedness Condition. Accordingly the unassociated tones which resulted from the deletion of a vowel would then be associated with the following vowel, resulting in a falling or rising tone.

(16)  LH L H H L H L
     | [‘‘] | [‘‘] |
     o k o k p a o w o w a
The combination of two like-toned vowels, as in the case of èkè élà → èkèlè èkèlè ‘three rams,’ brings out another principle of the theory. By the operation of vowel deletion and reassociation of the floating tone, one would expect the following representation.

(17) \[ \text{HHHL} \]
\[ e \text{k} e \text{l} a \]

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 Mongo. 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 in the complex three-tone contours fall–rise (FR) and rise–fall (RF).

(19)
\[ \begin{align*}
H+H \rightarrow H & \quad \text{bètámbá bêfê} \rightarrow \text{bètámbêfê} \quad \text{‘two trees’} \\
L+L \rightarrow L & \quad \text{lâ ìtókò} \rightarrow \text{litokò} \quad \text{‘with the fork’} \\
H+L \rightarrow F & \quad \text{mpûlû ìnê} \rightarrow \text{mpûdûwînê} \quad \text{‘these birds’} \\
L+H \rightarrow R & \quad \text{là bûnà} \rightarrow \text{lûnà} \quad \text{‘with the baby’} \\
H+F \rightarrow F & \quad \text{sôngoló } \text{Ôswê} \rightarrow \text{sôngolÔswê} \quad \text{‘may S. enter’} \\
H+R \rightarrow FR & \quad \text{bâlângâ } \text{bàkàè} \rightarrow \text{bâlångâ kàè} \quad \text{‘his blood’} \\
L+F \rightarrow RF & \quad \text{fàkàlà } \text{Ôswà} \rightarrow \text{fàkàlà Ôswà} \quad \text{‘F. comes in’} \\
L+R \rightarrow R & \quad \text{bànkû bàmsô} \rightarrow \text{bànkàmsô} \quad \text{‘those others’} \\
R+F \rightarrow RF & \quad \text{sômsò } \text{ëmbê} \rightarrow \text{sômsê mbê} \quad \text{‘may someone else sing’}
\end{align*} \]

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 with the following vowel by the Well-formedness 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)
\[ \begin{align*}
\text{LH LH HL L} & \rightarrow \text{LH LH HL L} \\
\text{ômô e mb e} & \rightarrow \text{ômô e mb e} \\
\text{LH LH HL L} & \rightarrow \text{LH L} \\
\text{ômô e mb e} & \rightarrow \text{ômô e mb e}
\end{align*} \]
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.

### 9.1.4 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.

<table>
<thead>
<tr>
<th>(21) N with N like N of N</th>
</tr>
</thead>
<tbody>
<tr>
<td>mbwá né-mbwá sé-mbwá</td>
</tr>
<tr>
<td>hóvé né-hóvé sé-hóvé</td>
</tr>
<tr>
<td>mbündúdzí né-mbündúdzí sé-mbündúdzí ché-mbündúdzí ‘army worm’</td>
</tr>
<tr>
<td>hákátà né-hákátà sé-hákátà ché-hákátà ‘bones’</td>
</tr>
<tr>
<td>bénzibvúnzá né-bénzibvúnzá sé-bénzibvúnzá ché-bénzibvúnzá ‘fool’</td>
</tr>
</tbody>
</table>

As shown in (22) and by the last example of (21), an H tone which is not part of an initial string of H’s will not undergo this lowering process.

<table>
<thead>
<tr>
<th>(22) N with N like N of N</th>
</tr>
</thead>
<tbody>
<tr>
<td>műrúmé né-műrúmé sé-műrúmé ché-műrúmé ‘man’</td>
</tr>
<tr>
<td>bàdzá né-bàdzá sé-bàdzá ché-bàdzá ‘hoe’</td>
</tr>
</tbody>
</table>

The problem is that if we look at a word such as *mbündúdzí* 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) V → [−H]/ se, ne, che _
     [+H]        [+H]
```

Beginning from /né-mbündúdzí/, this rule would apply to the first H-toned vowel giving *né-mbündúdzí*. 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-műrúmé* that the rule does not apply to noninitial 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 with a number of vowels.

```
(24) H                       H
    mbwa                    hove
 H                       H
 mbundudzi               benzibvunza
```
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.

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 an L tone and the noun keeps its H tones.

However, if there are three of these prefixes, the second prefix has an L tone, and lowering also affects the first (apparent) string of tones in the noun.

A simple statement like “lower a sequence of adjacent H’s” after an 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.

The lowering of H on che gives that prefix an 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 2 from lowering prefix 3. Since prefix 3 keeps its H tone, it therefore can cause lowering of H in the noun.

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.
9.1.5 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 analyzed as falling into one of five tone melodies, illustrated in (30).

(30) H háwámá ‘waist,’ pëlı́ ‘house,’ k₃ ‘war’
     L kpàkàlì ‘three-legged chair,’ bëlë ‘trousers,’ kpà ‘debt’
    HL fëlàmà ‘junction,’ kënyà ‘uncle,’ mbà ‘owl’
   LH ndàvulà ‘slung,’ fändé ‘cotton,’ mbà ‘rice’
  LHL níkìlì ‘groundnut,’ nyàhà ‘woman,’ mbà ‘companion’

If tones were completely unrestricted, then given five surface tones, one would predict twenty-five patterns for bisyllabic words and 125 patterns for trisyllabic words. Instead, one finds five patterns no matter how many vowels there are.

(31) LHL   L H L   LH L
      níkìlì   nyàhà   mbà

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, níkìlì, nyàhà, and mbà all have the same tonal representation.

9.1.6 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 ètò, with M tone on its two vowels. However, it surfaces as [ètò] with L tones, either phrase-finally or when the following word has an L tone.

(32) ètò   ‘buffalo’   ètò mè   ‘in a buffalo’
      ètò wëlë   ‘buffalo-buying’   ètò djí   ‘on a buffalo’
      ètò mëgbé   ‘behind a buffalo’

These alternations are explained by two rules; one rule lowers M (mid) 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 ētō, then [ētō].
Two other tone rules are exemplified by the data in (34).

(34) ētō ‘mountain’ ētō djí ‘on a mountain’
ētō mēgbé ‘behind a mountain’

Here, we see a process which raises M to Superhigh tone (SH) when it is surrounded by H tones; subsequently a nonfinal H tone assimilates to a preceding or following SH tone.

(35) M→SH/H_H H→SH% SH_

We know from ētō mēgbé ‘behind a buffalo’ that mēgbé has the tones MH. Therefore, the underlying form of ētō mēgbé ‘behind a mortar’ is ētō mēgbé. The underlying form is subject to the rule raising M to SH since the M is surrounded by H tones, giving ētō mēgbé. This then undergoes the SH assimilation rule. Another set of examples illustrating these tone processes is (36), where the noun /àtjíkē/ ends in the underlying sequence HM. When followed by /mēgbē/, 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 an SH tone, and the preceding syllable then assimilates this SH.

(36) àtjíkē ‘root’ àtjíkē φēpē ‘root-buying’
àtjíkē mēgbé ‘behind a root’ àtjíkē djí ‘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 /φēpē/, the initial tone of the participle mysteriously changes to H; the following L-toned postposition mē inexplicably has a falling tone; the postposition /mēgbē/ mysteriously has an initial SH tone.

(37) ētō ‘mortar’ ētō φēpē ‘mortar-buying’
ētō mē ‘in a mortar’ ētō djí ‘on a mortar’
ētō mēgbé ‘behind a mortar’

All of these mysteries are resolved, once we recognize that this noun actually does not end with an M tone, but rather ends with an H tone that is not associated with a vowel, thus the underlying form of the noun ‘mortar’ is (38).

(38) e t o
    |   |
    M M H

Because this noun ends in a (floating) H tone and not an M tone, the rule lowering prepausal M to L does not apply, which explains why the final tone does not lower. The floating H at the end of the noun associates with the next vowel if possible, which explains the appearance of an 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 mēgbē. 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, where tones and features are not necessarily in a one-to-one relation.

**Mixtec.** Another example of floating tones can be seen in the language Mixtec. As (39) indicates, some words such as kēē ‘will eat’ have no effect on the tone of the following word, but other words such as the apparently homophonous verb meaning ‘will go away’ cause the initial tone to become H.

(39) sūtʃí ‘child’ kēē ‘will go away’
kōō ‘snake’
kēē sūtʃí ‘the child will eat’
kēē kōō ‘the snake will eat’

A similar effect is seen in (40), where tākā ‘all’ has no effect on the following word, but máá ‘that’ causes raising of the initial tone of the next word.

(40) tākā sūtʃí ‘all the children’ máá sūtʃí ‘that child’
tākā bēʔē ‘all the houses’ máá bēʔē ‘that house’
tākā kōō ‘all the snakes’ máá kōō ‘that snake’
tākā mínī ‘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
    ‘will eat’ ‘will go away’ ‘all’ ‘that’

When a word ending in a floating H tone, such as ‘will go away’ or ‘that’, is followed by another word, that H associates to the first vowel of the next word and replaces the initial lexical tone. When there is no following word, the floating tone simply deletes.

**Gā.** Other evidence for floating tones comes from Gā. Some of the evidence for floating L tone in this language involves the phenomenon of “downstep,” which is the contrastive partial lowering of the pitch level of tones at a specified position. Downstep is exemplified in Gā with the words [kātōkō] ‘porcupine,’ [ōnūfǔ] ‘snake,’ and [ātātū] ‘cloud.’ In ‘porcupine,’ the syllable
[tɔ] has H and the following syllable [kɔ] has L – the physical pitches are maximally separate. The second and third syllables of ‘snake’ are both H and are not physically distinct – they are produced at the same pitch, at the top of the voice range. In the third example, the syllable [tɔ] has the same high pitch that all of the second syllables of these words have, and the following syllable, which is phonologically H-toned, has a pitch physically between that of the L-toned syllable of [kɔtɔkɔ] and the H-toned syllable of [ önũfũ]. What happens here is that the pitch range of all tones is lowered after the second syllable of [áticasú], even those of a following word. This lowering of pitch range, notated with “!”, is known as “downstep.” A floating L between H tones is what in fact generally causes downstep.

In Gã, there is a rule changing the tone sequence HL before pause into H!H. The operation of this rule can be seen in the data of (42), where the presence of the future tense prefix -báá- causes a change in the tone of final L-toned verbs with the shape CV (the unmodified tone of the root is seen in the 3sg past form).

(42) 3sg past 3sg future
è-tɔá è-báá-tɔá ‘dig’
è-dɔò è-báá-dɔò ‘dance’
è-gbè è-báá-gbè ‘kill’
è-kpè è-báá-kpè ‘sew’
è-fɔ è-báá-fò ‘pull’
è-tɔù è-báá-tɔù ‘jump’
è-wɔ è-báá-wɔ ‘wear’

The necessity of restricting this rule to HL before pause is demonstrated by examples such as èbáágbè Άkɔ ‘he will kill Ako,’ èbáakpè ȃtādè ‘he will sew a shirt,’ èbáafɔ kpàŋ ‘he will pull a rope.’ In such examples, the tone sequence is not prepausal, and the underlying L is retained in phrase-medial position, whereas the verb has ʰH tone in prepausal position in (42).

The restriction to applying just to prepausal HL 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, since another L tone follows it.

(43) 3sg past 3sg future
è-gbè è-báá-gbè ‘hunt’
è-hàò è-báá-hàò ‘worry’
è-sɔè è-báá-sɔè ‘catch’
è-sɔlè è-báá-sɔlè ‘pray’
è-hàlà è-báá-hàlà ‘chose’

A further restriction is that this rule does not apply to tense-inflections on verbs, for example the plural imperative -à (mē-hē-à ‘buy (pl)!’) or the habitual -ɔ (è-màdɛ-ɛ-ɔ ‘he sends’).
A second relevant rule of Gà is Plateauing, whereby HLH becomes H!HH. This can be seen in (44) involving verbs with final HL. If the following word begins with L tone, the final L of the verb is unchanged. When the following object begins with an H tone, the resulting HLH sequence becomes H!HH by the Plateauing rule.

(44) jé-hé-à  ‘buy (pl)!’
    jé-hé-’à tú  ‘buy (pl) a gun!’
    jé-hé-à fó  ‘buy (pl) oil!’
    è-màd’é-à akò  ‘he sends Ako’
    è-màd’é-ó akú  ‘he sends Aku’
    mìggè kwàkwè  ‘I am killing a mouse’
    mìg’gbè fótè  ‘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 an H-toned prefix, such as the future prefix.

(45) 3sg past 3sg future
è-hùlù è-bàá-hùlú  ‘jump’
è-kàsé è-bàá-kàsé  ‘learn’
è-kòd’é è-bàá-kòd’é  ‘judge’
è-màd’é è-bàá-màd’é  ‘send’

Again, by the Plateauing rule, è-bàá-hùlú/ becomes [è-bàá-húlú].

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 tenses are identical: their difference lies in their tone. In both tenses the subject prefix has an H tone. In the perfective, the rule affecting prepausal HL exceptionally fails to apply to an L-toned CV stem, but in the subjunctive that rule applies as expected.

(46) 3sg subjunctive 3sg perfective
è-t’a è-t’a  ‘dig’
è-d’ò è-d’ò  ‘dance’
è-gbè è-gbè  ‘kill’
è-kpè è-kpè  ‘sew’
è-f’s è-f’s  ‘pull’
è-wò è-wò  ‘wear’

You might think that the perfective is an exception to the general rule turning HL into H!HH, but there is more to it.

Another anomaly of the perfective is that the Plateauing rule fails to apply between the verbs of (46) and the initial H tone of a following word, even though the requisite tone sequence is found.

(47) é-gbè ákú  ‘he has killed Aku’
è-f’s gú’ògò  ‘he has pulled a nose’
è-wò d’wo’è  ‘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), and we can identify a L tone which has no associated vowel as being the morpheme marking the perfective.

(48)  
\[
\begin{array}{c}
H \\
\hline \\
L \\
\hline \\
L \\
\end{array}
\]
\[
e - wo
\]

The floating L between the H and the L of the root means that the H is not next to the prepausal L, and therefore the rule changing HL into H’H cannot apply. 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 L 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 verb roots 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 an H-toned prefix; the perfective data show that in the perfective tense, Plateauing fails to apply within the word, because of the floating L of the perfective.

(49)  
\[
\begin{array}{lll}
3sg past & 3sg subjunctive & 3sg perfective \\
è-hùlú & é-hùlú & é-hùlú & ‘jump’ \\
è-kásé & é-kásé & é-kásé & ‘learn’ \\
è-kòd’ó & é-kòd’ó & é-kòd’ó & ‘judge’ \\
è-màd’è & é-màd’è & é-màd’è & ‘send’ \\
\end{array}
\]

Again, these facts can be explained by positing a floating L 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)  
\[
\begin{array}{c}
H \\
\hline \\
L \\
\hline \\
L \\
\hline \\
H \\
\end{array}
\]
\[
e - hulu
\]

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 in the perfective, but not in the subjunctive.

(51)  
\[
\begin{array}{lll}
3sg past & 3sg subjunctive & 3sg perfective \\
è-bè & é-bè & é-bè & ‘quarrel’ \\
è-t’ú & é-t’ú & é-t’ú & ‘send’ \\
è-dú & é-dú & é-dú & ‘cultivate’ \\
è-fó & é-fó & é-fó & ‘weep’ \\
è-fòtè & é-fòtè & é-fòtè & ‘pour’ \\
è-d’álè & é-d’álè & é-d’álè & ‘rinse’ \\
\end{array}
\]
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.

9.1.7 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)’ téŋ ‘rope (modified)’
mús ‘cat’ mús ‘cat (case)’ mús ‘cat (mod.)’
téén ‘hoe’ téén ‘hoe (case)’ téén ‘hoe (mod.)’
ñí ‘elephant’ ñí ‘elephant (case)’ ñí ‘elephant (mod.)’
ʔás ‘dog’ ñás ‘dog (case)’ ñás ‘dog (mod.)’
zwál ‘boy’ zwál ‘boy (case)’ zwál ‘boy (mod.)’
jém ‘child’ jém ‘child (case)’ jém ‘child (mod.)’
màs ‘locust bean’ màs ‘bean (case)’ màs ‘bean (mod.)’
pûk ‘soup’ pûk ‘soup (case)’ pûk ‘soup (mod.)’
ʔás ‘tooth’ ñás ‘tooth (case)’ ñás ‘tooth (mod.)’
djolì ‘ape’ djolì ‘ape (case)’ djolì ‘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 an H tone or an L tone on the first syllable of the root. The general past tense is marked with a floating L tone; the past habitual with an H; the recent past with the tone sequence HL.

(53) H verbs L verbs

*General past (L)*

vá ‘come’ dìá ‘go’
úngwà ‘hear’ vèndè ‘refuse’
jévèsè ‘flee’ ngòhòrò ‘accept’

*Past habitual (H)*

vá dìá
úngwà vèndè
ejévèsè ngòhòrò

*Recent past (HL)*

vá dìá
úngwà vèndè
ejévèsè ngòhòrò
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 derived. The concatenation of the L root *ngohoro* and the recent past morpheme gives the following underlying form:

\[(54) \quad \text{L H L} \]

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**.

\[(55) \quad \text{Link free tones to free vowels, one-to-one, from left to right} \]

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 with 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 with vowels simply does not link a floating tone with a vowel that already has a tone, or floating tones do associate with vowels that already bear an H and then some later rule eliminates tonal contour tones. If we assume that floating tones are all initially associated with a vowel and contours are later eliminated, we will require the following rule, which deletes the L-tone component of a falling tone.

\[(56) \quad \text{H L} \rightarrow \emptyset \]

Finally, we come to *dzàl*, which has H if one of the floating tone patterns H or HL is added to the root. This can be explained if floating tones are associated with root vowels even when this would result in a contour tone. Linking the melodic tones to this root would result in the following representation:

\[(57) \quad \text{L H L} \]

Rule \((56)\) applies in a mirror-image fashion: it deletes L in combination with an H on one vowel, standing before or after the H. This explains why the lexical L is replaced with an H. Under the alternative account, that floating tones only link to vowels which do not have any other tone, we
would be unable to explain why the lexical L is replaced by H when a melodic pattern with an H tone is added.

### 9.1.8 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 /ɗə/ ‘buy,’ /skə/ ‘wait,’ and /nə/ ‘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) 
\[
\begin{align*}
\text{ɗə} + \text{bá} & \rightarrow \text{ɗə-bá} & \text{‘to sell’} \\
\text{ndə} + \text{bá} & \rightarrow \text{ndə-bá} & \text{‘to throw out’} \\
\text{dəl} + \text{bá} & \rightarrow \text{dəl-bá} & \text{‘to buy’} \\
\text{nə} + \text{də} & \rightarrow \text{nə-də} & \text{‘give me’} \\
\text{hər} + \text{də} & \rightarrow \text{hər-də} & \text{‘bring me’} \\
\text{skə} + \text{də} & \rightarrow \text{skə-də} & \text{‘wait for me’} \\
\text{tə} + \text{nə} & \rightarrow \text{tə-nə} & \text{‘to cook and put aside’} \\
\text{ndə} + \text{nə} & \rightarrow \text{ndə-nə} & \text{‘to throw away’} \\
\text{də} + \text{nə} & \rightarrow \text{də-nə} & \text{‘to sell’}
\end{align*}
\]

As (59) indicates, this can be accounted for by spreading tone (i.e. adding associations between tone and vowels) to toneless vowels.

(59) 
\[
\begin{align*}
\text{ɗə} + \text{bá} & \rightarrow \text{ɗə-bá} & \text{‘to sell’} \\
\text{ndə} + \text{bá} & \rightarrow \text{ndə-bá} & \text{‘to throw out’} \\
\text{dəl} + \text{bá} & \rightarrow \text{dəl-bá} & \text{‘to buy’} \\
\text{nə} + \text{də} & \rightarrow \text{nə-də} & \text{‘give me’} \\
\text{hər} + \text{də} & \rightarrow \text{hər-də} & \text{‘bring me’} \\
\text{skə} + \text{də} & \rightarrow \text{skə-də} & \text{‘wait for me’} \\
\text{tə} + \text{nə} & \rightarrow \text{tə-nə} & \text{‘to cook and put aside’} \\
\text{ndə} + \text{nə} & \rightarrow \text{ndə-nə} & \text{‘to throw away’} \\
\text{də} + \text{nə} & \rightarrow \text{də-nə} & \text{‘to sell’}
\end{align*}
\]

The form /dəl-nə/ ‘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) 
\[
\begin{align*}
\text{ɗə} + \text{bá} & \rightarrow \text{ɗə-bá} & \text{‘to sell’} \\
\text{ndə} + \text{bá} & \rightarrow \text{ndə-bá} & \text{‘to throw out’} \\
\text{dəl} + \text{bá} & \rightarrow \text{dəl-bá} & \text{‘to buy’} \\
\text{nə} + \text{də} & \rightarrow \text{nə-də} & \text{‘give me’} \\
\text{hər} + \text{də} & \rightarrow \text{hər-də} & \text{‘bring me’} \\
\text{skə} + \text{də} & \rightarrow \text{skə-də} & \text{‘wait for me’} \\
\text{tə} + \text{nə} & \rightarrow \text{tə-nə} & \text{‘to cook and put aside’} \\
\text{ndə} + \text{nə} & \rightarrow \text{ndə-nə} & \text{‘to throw away’} \\
\text{də} + \text{nə} & \rightarrow \text{də-nə} & \text{‘to sell’}
\end{align*}
\]

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 pò ‘it is not plentiful’ kò dù ‘it is not sweet’
    ó pò ‘it is plentiful’ ó dù ‘it is sweet’
    Jak ‘lesson’ ìbì ‘monkey’
    Àfù ‘mournning’ gígá ‘height’
    Ìjé ‘work’ ìdù ‘snake’

The question is how to exclude M tone from being targeted by this rule, and how to prevent M tone from spreading. If we assume that tonally unspecified vowels are assigned an 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) \[
\begin{array}{c}
  T \\
  \hline
  . . . \\
  \hline
  V \\
  \hline
  V
\end{array}
\]

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.

9.1.9 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 Nkore, 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 prepausal 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

| òkúgúrú | ‘leg’ | òkúgúrú kùrùùnjí | ‘good leg’ |
| òmúkózí | ‘worker’ | òmúkózí mùrùùnjí | ‘good worker’ |
| èmúzi | ‘goat’ | èmúzi nùùnjí | ‘good goat’ |
| èchikópò | ‘cup’ | èchikópò chirùùnjí | ‘good cup’ |
| èmbímò | ‘seeds’ | èmbímò nùùnjí | ‘good seeds’ |

Nouns with final H

| òmúgúzí | ‘buyer’ | òmúgúzí mùrùùnjí | ‘good buyer’ |
| òmúkáma | ‘chief’ | òmúkáma mùrùùnjí | ‘good chief’ |
| èèmbùwà | ‘dog’ | èèmbùwà nùùnjí | ‘good dog’ |
| èbúrò | ‘millet’ | èbúrò bùrùùnjí | ‘good millet’ |
| kàsúkù | ‘parrot’ | kàsúkù nùùnjí | ‘good parrot’ |
There are a number of reasons internal to the grammar of Nkore for treating L tone as the default tone, and for only specifying H tones in the phonology so that phonetically L-toned vowels are actually toneless. This alternation can be accounted for by the following rule of tone-throwback.

(64)  
\[ H \xrightarrow{\text{V \ C\_0\ V \ \#\#}} \]

Another example of tone shift can be seen in Kikuyu. Like Nkore, there are good reasons to analyze this language phonologically solely in terms of the position of H tones, with vowels not otherwise specified as H being realized 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), illustrating 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 an H tone: this happens only when 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 an 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 an H tone.

(65)  
a. to -rö-'r-aγ -a  
we-look at-hab-tense  
to -mo -rö- -aγ -a  
we-him-look at-hab-tense  
to -ma -rö- -aγ -a  
we-them-look at-hab-tense

b. to-tom-áγ-a  
we send

to-mo-tom-áγ-a  
we send him

to-ma-tom-áγ-a  
we send them

It is clear, then, that certain syllables have 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 -rör- and -tom-: we can see that the syllable after -tom always receives an H tone.

(66)  
to -rö-rer- -aγ -a  
we look for

to-tom-ér- -aγ -a  
we send for

to -rö- ran -aγ -a  
we look at each other

to-tom-án- -aγ -a  
we send each other

to -rö-rer- -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 an 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 an H tone to the following vowel.

(67) a. to-a-rár-a  ‘we looked at’
    to-a-mó-rár-a  ‘we looked at him’
    to-a-má-rár-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’

We would assume that the root -tóm- has an H, as do 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) H
    ̂* ... ̀ ́
    V  ...  V#

Thus, /to-tóm-er-ay-á/ becomes totoméraya, /to-má-rár-ay-á/ becomes tomaríraya, and /to-á-má-tóm-á/ becomes toamátómá.

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 realized on the last vowel of the word. Similarly, the root togorá is toneless, as is the subject prefix ni, but the third-singular subject prefix a has an H tone, which shifts to the end of the word. Lastly, the root tťukura is toneless, as is the tense-aspect prefix -na-, but the perfective prefix ka has an H tone which shifts to the last vowel of the word.

(69) H  H  H
    ̂* ... ̀ ́ ́ ́
    t o a má  t o má

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.

(70) a. ku-vugura  ‘to untie’  ku-vugurirá  ‘to untie for’
    ku-ni-vugurirá  ‘to untie for me’  ku-a-vugurirá  ‘to untie for them’

    b. ku-tŏgorá  ‘to praise’  ni-na-tŏgorá  ‘I’m praising’
    a-na-tŏgorá  ‘he’s praising’

    c. ku-tťukura  ‘to carry’  ni-na-tťukura  ‘I’m carrying’
    a-na-tťukurá  ‘he’s carrying’  ni-ka-tťukurá  ‘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) H
    ̂* ... ̀ ́
    V  ...  V#
9.2 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, 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 is, 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.

9.2.1 The autonomy of all features

An example of segmental phenomena which are reminiscent of autosegmental tonal properties is floating segmental features as morphemes. One such case is seen in Vata, where the past-tense marker can be argued to be simply the specification [+high], which is suffixed to the stem and is realized phonetically on the last vowel.

(72) n le 'I eat' n li 'I ate'
    n ple 'I pass' n pli 'I passed'
    n mlɛ 'I go' n mlɛ 'I went'
    n no 'I hear' n nu 'I heard'
    n zo 'I place' n zo 'I placed'
    n woɓ 'I wash' n woŋo 'I washed'

A second example comes from Fula, where a particular 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'
    wibdɔ bibtɛ 'wing'
    ruulde duule 'cloud'
    sekko cekke 'mat'
    hello kelle 'slap'
    jeɓre dɛʃel 'seed'
    jimre dɛimel 'poem'
    jontere dɔnte 'week'

Aramaic CP. Azerbaijani Aramaic provides evidence for treating the feature [constricted pharynx] ([CI]) autosegmentally. This dialect has a contrast between pharyngealized or emphatic vowels (A E I U O) specified as [+CP], and plain vowels (a e i u o). In most words, either all of the vowels are emphatic, or none of them is.
Some words may have nonemphatic vowels followed by emphatic vowels. In such a case, the first emphatic vowel is always a low vowel.

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.

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:

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 with any particular vowel, but is just floating, and an unassociated [+CP] specification is associated with the first vowel of the word by the following rule:
The derivation of \( \text{mI} \int \text{ItUn-Un} \) ‘make a king (pl)’ shows these rules.

There are some suffixes whose vowels are invariably emphatic; that vowel is always the vowel [A]. No suffixes are invariably plain.

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 with the first vowel of the word, and since it does not associate with 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.

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.

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.

\[
\begin{array}{c}
\text{[+CP]} \\
xwara diqna
\end{array} \rightarrow \begin{array}{c}
\text{[+CP]} \\
xwara diqna
\end{array} \rightarrow \begin{array}{c}
\text{[+CP]} \\
xwara diqna
\end{array}
\]

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.

\[
\begin{array}{cccc}
\text{xoʃ} & \text{‘good’} & \text{na-xoʃ} & \text{‘ill’} \\
hAq & \text{‘right’} & nA-hAq & \text{‘wrong’} \\
rAzI & \text{‘satisfied’} & nA-rAzI & \text{‘unsatisfied’} \\
pjala & \text{‘fall’} & ma-pole & \text{‘cause to fall’} \\
jatoe & \text{‘drink’} & ma-stoe & \text{‘give drink’} \\
mjAsA & \text{‘suck’} & mA-mOsE & \text{‘give the suck’} \\
rAdOxE & \text{‘boil (intr.)’} & mA-rdOxE & \text{‘boil (tr.)’}
\end{array}
\]

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 with a noninitial 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],

\[
\begin{array}{ccc}
xaraba & \text{‘ruined’} & xArAb-IstAn \text{ ‘ruined place’} \\
tʃol & \text{‘uninhabited land’} & tʃOl-IstAn \text{ ‘wilderness’} \\
hInd & \text{‘India’} & hInd-IstAn \text{ ‘India’}
\end{array}
\]

This makes sense if the suffix -istan also has a floating specification [+CP], which automatically associates with the first vowel of the stem and then spreads rightward.

\[
\begin{array}{c}
\text{[+CP]} \\
xarab – istan
\end{array} \rightarrow \begin{array}{c}
\text{[+CP]} \\
xarab – istan
\end{array} \rightarrow \begin{array}{c}
\text{[+CP]} \\
xarab – istan
\end{array}
\]

9.2.2 Feature geometry
It was realized that all features are autonomous from all other features, and 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 with, 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.”

The organization 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. We have discussed rules of nasal place assimilation in previous chapters, and noted in chapter 6 that such rules necessitate a special notation, the feature variable notation using α, β, γ, and so on. The notation makes some very bad predictions. First, notice that complete place assimilation requires specification of ten features in total.

\[
\begin{align*}
C & \rightarrow [\alpha_{\text{coronal}}] / {} \\
& \quad [\beta_{\text{anterior}}] / {} \\
& \quad [\gamma_{\text{back}}] / {} \\
& \quad [\delta_{\text{high}}] / {} \\
& \quad [\theta_{\text{distributed}}] / {}
\end{align*}
\]

This is less simple and, by the simplicity metric used in that theory, should occur less frequently than (90).

\[
(90) \quad C \rightarrow [\alpha_{\text{coronal}}] / {} [\alpha_{\text{coronal}}]
\]

This prediction is totally wrong: (90) 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:

\[
\begin{align*}
\text{nt}^f & \rightarrow \text{nt}^f (\text{not pt}^f) \\
\text{np} & \rightarrow \eta \text{p} \\
\text{nk} & \rightarrow \eta \text{k} \\
\text{nt} & \rightarrow \eta \text{t}
\end{align*}
\]

\[
\begin{align*}
\text{nt}^f & \rightarrow \text{nt}^f \\
\eta \text{p} & \rightarrow \eta \text{p} \\
\eta \text{k} & \rightarrow \eta \text{k} \\
\eta \text{t} & \rightarrow \eta \text{t}
\end{align*}
\]
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 a minor difference in naturalness between (92) and (89), since the rules are the same except that (92) does not include assimilation of the feature \[\text{anterior}\].

\[\text{(92)}\]
\[
\begin{array}{c}
\alpha \text{coronal} \\
\gamma \text{back} \\
\delta \text{high} \\
\theta \text{distributed}
\end{array}
\]
\[
\begin{array}{c}
\alpha \text{coronal} \\
\gamma \text{back} \\
\delta \text{high} \\
\theta \text{distributed}
\end{array}
\]

There is a huge empirical difference between these rules: (89) is very common, (92) is unattested. Rule (92) is almost complete place assimilation, but \[\text{anterior}\] is not assimilated, so \[\text{np}, \text{ŋk}, \text{mt}\] become \[\text{mp}, \text{ŋk}, \text{nt}\] as expected, but \[\text{ŋp} \text{and ŋt} \text{do not assimilate} \text{(as they would under complete place assimilation)}\]; similarly, \[\text{ŋʃ}\] becomes \[\text{np}\] as expected (and as well attested), but \[\text{ŋt} \text{and ŋt} \text{do not assimilate (as they would under complete place assimilation)}\]; similarly, \[\text{ŋʃ}\] becomes \[\text{ŋp}\] and \[\text{ŋt}\] become \[\text{np}\] and \[\text{nt}\], since the underlying value \[\text{– anterior}\] 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.

The variable-feature theory gives no special status to a rule where both occurrences of \[\alpha\] occur on the same feature.

\[\text{(93)}\]
\[
\begin{array}{c}
\alpha \text{coronal} \\
\beta \text{anterior} \\
\gamma \text{back} \\
\delta \text{high} \\
\theta \text{distributed}
\end{array}
\]
\[
\begin{array}{c}
\theta \text{coronal} \\
\alpha \text{anterior} \\
\beta \text{back} \\
\gamma \text{high} \\
\delta \text{distributed}
\end{array}
\]

This rule describes an equally unnatural and unattested process whereby a consonant becomes \[\text{t}\] before \[\text{p}^\prime\], \[\text{p}\] before \[\text{q}\], and \[\text{p}^\prime\] before \[\text{k}\]. Rules such as (93) 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.

The variable notation allows us to refer to legions of unnatural classes by randomly linking two unrelated features with a single variable:

\[\text{(94)}\]
\[\begin{array}{c}
\alpha \text{high} \\
\alpha \text{round}
\end{array}\]
\[\begin{array}{c}
\alpha \text{distributed}
\end{array}\]
\[\begin{array}{c}
\alpha \text{coronal} \\
\alpha \text{anterior}
\end{array}\]
\[\begin{array}{c}
\alpha \text{voice} \\
\alpha \text{lateral}
\end{array}\]

Class (a) applied to vowels refers to \[\text{y, u, e, a, a}\]; (b) refers to \[\text{ɕ, n, p, t, k}\] but excludes \[\text{m, ŋ, ŋ, ŋ, ŋ}\]; (c) groups together \[\text{t, k}\] and excludes \[\text{p, ŋ}\]; (d) refers to \[\text{l}\] plus voiceless consonants. Such groupings are not attested in any language.

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 formulated 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 \[\text{ŋ} \rightarrow \text{m} / \text{p}\] is seen as working as in (95):
Just as 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. The hypothesis is that phonological rules can perform one simple operation (such as spreading, inserting or deletion) on a single element (a feature or organizing node in the feature tree).

The thrust of much work on the organization 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 example, that the features which characterize 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 (94), 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 (92), which involves 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 (93) 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. 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 (each has a common property) – and, in actual phonological processes, these segments do function as natural classes – the complements of these sets do not function as units in 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 ([p, k] excluding [t, tʃ]) in this theory. 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 noncoronals 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 nonflowers”). Importantly, phonological rules do not ever seem to refer to the group [−coronal], even though the class [+coronal] 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 [tʃ, 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 [tʃ, k] together.

### 9.3 Suprasegmental structure

Another aspect of nonlinear representational theory is the claim that there are phonologically significant structures above the level of the segment, i.e. units that encompass multiple segments. Such structures are referred to as “prosodic,” a term which refers to poetic meter, rhythm, and singing, which are aspects of language use that involve “how strings of segments are performed.” The best-known unit of prosody is the traditional concept of the syllable. The term itself is one of the oldest in linguistics, originating from Ancient Greek sullabe, but the nature of the syllable and arguments for it have been elusive. At various points in contemporary linguistics, scholars have rejected or embraced the syllable, and the syllable was not part of standard generative phonological theory, until 1976 when Kahn produced strong arguments for it within autosegmental theory.

The intuitive concept of “syllable” is not particularly difficult to understand: it is a string of segments which centers around one or more vowels, and includes some consonants to the left and to the right. The problem
resides in justifying the addition of this concept to our arsenal of analytical devices. In segmental representations, there are audible consequences of features; for example you can hear voicing, nasality, and glottalization on segments, even though relating features to phonetic properties is difficult. The problem of the syllable is that it has no audible defining property, thus it cannot be justified as a prima facie transcriptional fact: no amount of ear training will enable you to “hear” how many syllables there are in a word of the form [CVVVC] in some unfamiliar language, and in [VCCCCV] you cannot “hear” where one syllable begins and the other ends. The evidence for the syllable is indirect, in that grouping sequences of segments into a unit can lead to a simpler account of certain phonological processes, in numerous languages.

Possible consonant clusters. One of the most widely invoked arguments of this nature regards the rules for possible consonant clusters, which reflect the fact that sequences of segments have to be organized into definable syllables, and languages impose various restrictions on how syllables can be formed. We will start with possible word-beginnings and word-ends in English, and see how these relate to syllable structure. Initial clusters may have the form sC (C=consonant), as in stick, spit, skunk, also snow, smile, slay, or they may be of the type OR (O=obstruent, R=glide or liquid) as in fray, through, fly, bleed, breed, pray, clue. The longest possible initial cluster has the shape sCR (sprint, sklerotic, strip, splice), which reflects the interaction of the two rules pertaining to possible initial consonant clusters.

Words which violate these rules cannot be words of English, thus consonant plus stop clusters other than sC are nonexistent and are judged by native speakers as being impossible (*bnick, *pnot, *tack, *dbonk, *fnilge). Likewise there are no stop+fricative clusters (*kmp, *kunk, *pting). Sonorants as the first member of a cluster are also excluded: *mbop, *rtot, *fay, *yluck, *wnurge. There are additional, more specific restrictions on the pattern of allowed initial clusters. For example, coronal plus l is excluded (*tluth, *dlifcult, *thlash, *chlort), except for [sl] (sleep) thanks to the special rule allowing sC clusters. Sequences of labial+w are also disallowed (*pwang, *bwint, *mmerge, *fwet).

Clusters of consonants at the end of English words are also subject to restrictions. Any consonant except h can stand at the end. Consonant clusters can be of the form sonorant-consonant. Thus, words can end with glide+consonant (height, clown, mouse, leaf), liquid plus consonant (halt, harp, hart, milk, false, film, born, farm, carl), or nasal+consonant (dance, runt, punk, brand, lamp, lymph, lense). There are certain restrictions on such final clusters. One is that in a nasal plus voiced stop cluster, the stop must be noncoronal, thus fringe, hand are allowed and *[læmb], *[hæŋ] with pronounced final [b], [g] are disallowed. The consonants [r j w] cannot be the second consonant in a cluster; [l] can follow [r j w] but not a nasal, and nasals can only follow [r j w].

Certain sequences of voiceless obstruents are also allowed, as long as either the second consonant is [+anterior, +coronal] (apt, act, depth, apse,
raft), or else the first consonant is /s/ (cast, cask, clasp). Obstruent sequences ending in a noncoronal or nonanterior consonant are excluded (‘atp, ‘atc, ‘lupsh, ‘ratf), as are clusters of fricative+obstruent where the fricative is not s (‘cashk, ‘lithp,‘rafk). Clusters ending with voiced obstruents are also disallowed (‘abd, ‘abz). Notice that all of these rules involve allowed or disallowed sequences of two consonants — no rules of combination specifically apply to just three-member clusters or four-member clusters, and observed limits on initial and final clusters all reduce to a chain of limits on two-consonant sequences. It is also important to note that certain otherwise excluded clusters do arise when inflectional affixes are added; for example the final cluster [bz] exists in the plural cabs and [gd] exists in past tense flagged, but such clusters only exist as combinations of root plus suffix.

The importance of the syllable in understanding these restrictions comes from the fact that these are not just restrictions on how words can begin or end, they are restrictions on how syllables can begin and end. Taken together, the preceding rules for syllable beginnings and endings define possible word-medial clusters. Some examples of allowed word-medial clusters are [tm] in atmosphere, [mb] in camber, [jr] in mushroom, [rt] in barter, [sb] in asbestos, [bn] in Abney, [md] in Camden, [db] in Ledbetter, [j] in ashan, and [k] in breakfast. Note that these are not possible initial or final clusters, except that [rt] is a possible final cluster. In such cases, the first consonant is the final consonant of one syllable, and the second is the initial consonant of the next syllable — [kæm.br], [bar.tr], [æb.nij], [led.br.tr], [brk.fasts]. Three-consonant clusters are possible, for example bolster, Andrew, hamster, translate, electron, costly, which can be arranged into a possible syllable-final sequence followed by a possible syllable-initial sequence, viz. [bol.str], [æn.druw], [haem.str], [traen.slejt], [ə.lek.tran], [kast.lj].

Now consider illicit three-consonant medial clusters, exemplified by *catmbop (‘[tmb]), *fishrrot ([rt], *gasbnick (‘[sbn]), *lamdbonk ([mdb]), *gushk-fimp (‘[k])f). We have seen that the individual consonant pairs are possible — [tm], [mb], [jr], [rt], [sb], [bn], [md], [db], [j], and [k] — but only because the first member is a syllable-final consonant and the second is syllable-initial. The three-consonant cluster *[tmb] is ruled out because tm is not a possible syllable-final cluster and mb is not a possible syllable-initial cluster, thus m cannot be assigned to any syllable — neither cat.mbop nor cat.mbo.p follows the rules for syllabification of consonants in English. Similarly, sb is not a possible syllable-final cluster and bn is not a possible initial cluster, thus the cluster in *gasbnick cannot be syllabified. A syllable-based analysis of possible clusters automatically predicts the restrictions on word-medial three-consonant clusters. Without the syllable as an organizing unit over segments, a very complex set of additional rules would be required to account for the restrictions on medial clusters.

**Phonological rules.** Rules of English consonant allophony discussed in chapter 2 also support the postulation of the syllable, insofar as those rules are best stated with reference to the syllable. The best-known such
rule is the aspiration rule. As is commonly recognized and explicitly assumed in our previous discussion of the aspiration rule, voiceless stops are aspirated at the beginning of a syllable, explaining the aspiration in \([p^h]t, p^[h]l, \ddot{a}^[h]r, \ddot{a}^[h]laj\) but not in \([sp]t, sp[la], sl[p]\).

Another rule of American English which refers to the syllable is the one glottalizing syllable-final voiceless stops, where /p t k/ become unreleased \([p \dddot{t} k\dddot{y}]\) after a vocoid in the same syllable. There is dialectal variation in the extent to which all voiceless consonants undergo this rule, but examples involving t (which is the most susceptible to glottalization) include \(hi\ddot{t}, hear\ddot{t}, cat\ddot{kin}, At\ddot{kins}, light, clout, heights, hearts, atlas, atlantic, and Watney’s. By contrast, there is no glottalization of t in \(st\ddot{em}, apt, belt, mattress, atrocious.\) In the word stem, t is clearly not preceded by a vocoid at all, so the conditions of the rule are not satisfied: likewise in apt and belt. In mattress, atrocious, the cluster tr is a cluster at the beginning of the second syllable, so while t is preceded by a vocoid, it is not in the same syllable. Consequently, there is no glottalization in these examples. On the other hand, there is glottalization in atlas, atlantic since *tl is not a permitted initial cluster in English; these words are syllabified as at\(\ddot{l}a\ddot{s}, at\ddot{lan.tic}.\) Likewise tr is not an allowed cluster at the beginning of the syllable, so Watney’s is syllabified Wat\ddot{ney}’s. Since t is in the same syllable as the preceding vocoid, the consonant becomes glottalized.

The rule of glottalization provides important evidence regarding the nature of the syllable. The required relationship between the target consonant and the triggering vocoid is that they must be in the same syllable – the consonant does not have to be at the end of the syllable, see [kwa\ddot{t}s] ‘quartz.’ This means that the “syllable” is not just a boundary ordered between segments – the phonological significance of the syllable goes beyond encoding the concepts “syllable-initial” and “syllable-final.” Being in a syllable is a property shared by a span of segments. Analogous to the autosegmental representation of H linked to multiple vowels in Shona seen in (24), the segments of [kwa\ddot{t}s] are linked to one syllable entity, notated as \(\sigma\).

\[(96)\]

\[
\begin{array}{c}
\sigma \\
kwarts \\
\end{array}
\]

The rule deriving glottalized consonants can accordingly be formulated as (97).

\[(97)\]

\[
\begin{array}{c}
\sigma \\
[-cons] [-voice,-cont] \rightarrow [+s.g.] \\
\end{array}
\]

**r-unrounding.** A third rule of English phonology providing evidence for the syllable is the one which pertains to rounding of r. In some dialects, r is realized both as a rounded and an unrounded rhotic approximant, \(\ddot{a}\) and \(\ddot{a}^w\), following the rule that \(i^w\) unrounds after a nonround vowel in the same syllable. Thus r is round in \(j\ddot{e}nd, j\dddot{r}\ddot{e}j, str\dddot{e}j, fr\dddot{e}j, fr\dddot{a}j, \ddot{a}^wcore, \ddot{a}^wtour\) where the vowel preceding r in the syllable is round, and in \(\ddot{a}^warray\) where the
preceeding vowel is in a separate syllable; but \( r \) is unrounded in \([\text{k}a\text{u}]\) car, \([\text{k}a\text{u}t]\) cart, \([\text{b}u]\) beer, \([\text{he}d]\) Harold. The following rule unrounds \( l\text{a}^{\text{\text{'}}}\) after a tautosyllabic nonround vowel.

(98) \[
\sigma \\
[+\text{cor}, -\text{cons}] \\
[-\text{rd}] \\
\]

**Vowel reduction.** Vowel reduction provides another argument for the syllable in English. The data below show, as we have observed in chapter 4, that unstressed vowels reduce to schwa.

(99) Reduced | Unreduced
---|---
\([\text{o}^\prime \text{l}\text{ew}]\) ‘allow’ | \([\text{a}^\prime \text{elow}]\) ‘aloe’
\([\text{o}^\prime \text{n}\text{oj}]\) ‘annoy’ | \([\text{a}^\prime \text{n}\text{alist}]\) ‘analyst’
\([\text{t}^\prime \text{o}\text{gr}^\prime \text{afij}]\) ‘telegraphy’ | \([\text{t}^\prime \text{rlo}^\prime \text{gr}^\prime \text{efik}]\) ‘telegraphic’

A simple statement like “an unstressed vowel becomes schwa” forms the core of the correct generalization, but the following data indicate that the matter is more complex, since the nature of the following consonants matters. In some cases, a CC cluster can stand between the target of reduction and the next vowel, but in other cases, a CC cluster blocks reduction.

(100) Reduced | Unreduced
---|---
\([\text{a}^\prime \text{b}\text{r}\text{ap}^\prime \text{t}]\) ‘abrupt’ | \([\text{a}^\prime \text{d}^\prime \text{ma}^\prime \text{nij}]\) ‘admonish’
\([\text{a}^\prime \text{t}\text{row}^\prime \text{faj}\text{es}]\) ‘atrocious’ | \([\text{a}^\prime \text{et}^\prime \text{l}\text{e}^\prime \text{nti}^\prime \text{k}]\) ‘atlantic’
\([\text{a}^\prime \text{str}^\prime \text{an}^\prime \text{amij}]\) ‘astronomy’ | \([\text{a}^\prime \text{en}^\prime \text{dij}^\prime \text{an}]\) ‘Andean’
\([\text{a}^\prime \text{frej}^\prime \text{d}]\) ‘afraid’ | \([\text{a}^\prime \text{r}^\prime \text{t}\text{stik}]\) ‘artistic’
\([\text{a}^\prime \text{el}^\prime \text{p}^\prime \text{e}^\prime \text{k}^\prime \text{a}^\prime \text{s}]\) ‘alpaca’

If we take cognizance of syllable boundaries, especially the ends of consonant clusters that are allowed in the beginning of the syllable, then the generalization becomes much clearer: unstressed vowels reduce to schwa in English when they are at the end of the syllable.

(101) Reduced | Unreduced
---|---
\([\text{a}^\prime \text{.b}\text{r}^\prime \text{ap}^\prime \text{t}]\) ‘abrupt’ | \([\text{a}^\prime \text{d}^\prime \text{ma}^\prime \text{nij}]\) ‘admonish’
\([\text{a}^\prime \text{.t}\text{r}^\prime \text{ow}^\prime \text{faj}\text{es}]\) ‘atrocious’ | \([\text{a}^\prime \text{et}^\prime \text{l}\text{e}^\prime \text{nti}^\prime \text{k}]\) ‘atlantic’
\([\text{a}^\prime \text{.str}^\prime \text{an}^\prime \text{amij}]\) ‘astronomy’ | \([\text{a}^\prime \text{en}^\prime \text{dij}^\prime \text{an}]\) ‘Andean’
\([\text{a}^\prime \text{.frej}^\prime \text{d}]\) ‘afraid’ | \([\text{a}^\prime \text{r}^\prime \text{t}\text{stik}]\) ‘artistic’
\([\text{a}^\prime \text{el}^\prime \text{p}^\prime \text{e}^\prime \text{k}^\prime \text{a}^\prime \text{s}]\) ‘alpaca’

**Other phenomena referring to the syllable.** Across languages, there has been a recurring puzzle regarding the expression of natural classes via features, and the role of word boundaries. The problem is that there exist many rules which treat a consonant and a word boundary alike, but
only for a specific set of rules. Many dialects of Arabic have such a rule, one of vowel epenthesis which inserts [i] after a consonant which is followed by either two consonants or one consonant and a word boundary. Thus in many dialects of Eastern Arabic, underlying /katab-t/ becomes [katabit] ‘I wrote’ and /katab-l-kum/ becomes [katabilkum] ‘he wrote to you pl’. The following rule seems to be required, in a theory which does not have recourse to the syllable.

\[\begin{align*}
\emptyset &\to [i] / C \quad \# \\
C &\to \begin{cases} 
C \\
\emptyset
\end{cases}
\end{align*}\]

Similarly, a number of languages, such as Yawelmani (chapter 6), have rules shortening long vowels when followed by two consonants or by a word-final consonant (thus /taxa:k’a/ → /taxa:k/ → [taxak] ‘bring!’). /do:s.hin/ [doshin] ‘report (nonfuture)’, which would be formalized as follows.

\[\begin{align*}
[+\text{syll}] &\to [-\text{long}] / \# \\
C &\to \begin{cases} 
C \\
\emptyset
\end{cases}
\end{align*}\]

The problem is that these rules crucially depend on the brace notation (“{…, …}”) which joins together sets of elements which have nothing in common, a notation which has generally been viewed with extreme skepticism. But what alternative is there, since we cannot deny the existence of these phenomena?

The concept of syllable provides an alternative way to account for such facts. What clusters of consonants and word-final consonants have in common is that in many languages syllables have the maximal structure CVX, therefore in /ta.xa:k/ and /do:s.hin/ where there is shortening, the long vowels have in common the fact that the long vowel is followed by a consonant – the syllable is “closed.” In contrast, in [do:.sol] ‘report (dubitative),’ no consonant follows the long vowel. Expressed in terms of syllable structure, the vowel-shortening rule of Yawelmani (and many other languages) can be expressed quite simply without requiring reference to the questionable brace notation.

\[\begin{align*}
\sigma \\
V &\to [-\text{long}] \\
C
\end{align*}\]

Another type of argument for the syllable is the domain argument, examples being the arguments from English glottalization and r-unrounding where the fact of being in the same syllable is a crucial condition on the rule. One example comes from Cairene Arabic, where pharyngealization spreads to all segments in the syllable (originating from some coronal sonorant – t and t′ are contrastive phonemes in Arabic, likewise ḍ and ḍ, s, and s′ and in some dialects r and r′). Pharyngealization also affects vowels via this pharyngealization-spreading rule. Examples of this distribution are [rʕaḅ] ‘Lord’ from /rʕab/ vs. [rab] ‘it sprouted’; [tʕi:n] ‘mud’ from /tʕi:n/ vs. [ti:n] ‘figs’; see especially the alternation [lʕaτi:f] ‘pleasant (m)’ ~ [lʕaτʕiːf] ‘pleasant (f)’ from /lʕatʕiːf/. The addition of the feminine affix l-ā’ has the consequence that the root-final consonant is
syllable final in the masculine, but initial in the following syllable in the feminine. The rule of pharyngealization is formalized in (105).

\[(105) \quad \sigma \quad \text{(mirror-image)}\]

Because of the syllabification differences between /lʕa.t:i:ʕ/ and /lʕa.t:i:.fa/ \(f\) is subject to the rule only in the masculine, despite the fact that the conditioning factor, a vowel with the pharyngealization feature (derived by spreading pharyngealization from the syllable-initial consonant), is immediately adjacent to the consonant in both cases.

Other suprasegmental units. In addition to the syllable, research has provided evidence for a number of other prosodic units. First, the syllable itself may have structure – the initial cluster of consonants form an onset constituent, the final cluster of consonants form a coda constituent, the vowel or vowels which form the heart of the syllable are the nucleus; the nucleus and coda together may constitute a rhyme constituent. Another prosodic unit related to the expression of syllabicity, length, syllable-weight, and tone-bearingness is the mora. Groups of syllables may themselves be organized into a higher-level unit relevant to rhythm and stress, known as the foot, and finally there may be a panoply of word- and phrase-level constituents such as the prosodic word, phonological phrase, and intonational phrase. Such matters are part of the ongoing research program of phonological theory.

**Summary**

Answering a simple problem, namely how to represent contour tones, led to ideas which not only solved the problem of contours, but also solved a whole array of problems related to tone. Since there is no reason to think that there should be a special theory just for tone, a natural development of these changes applied to tone was a general application of the autosegmental idea to all of phonology. This resulted in sweeping changes to the theory of phonology, and has resolved many earlier problems in how to state rules in a constrained manner. This generalization of the results in one area to an entire subdiscipline is typical of the progression of scientific theories.

**Exercises 1 Lulubo**

Note on tone marks: \([\text{v}]\) = rising from L to M, \([\text{v}]\) = falling from M to L, \([\text{v}]\) = rising from M to H and \([\text{v}]\) = falling from H to M. 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. The word [ənɖə] is the verb ‘I see’ in different tenses.

<table>
<thead>
<tr>
<th>Bare noun</th>
<th>Unfocused object</th>
<th>Focused object</th>
<th>Proper name</th>
</tr>
</thead>
<tbody>
<tr>
<td>ębì</td>
<td>əndʒe ɓi</td>
<td>əndʒe ɓi</td>
<td>‘lion’</td>
</tr>
<tr>
<td>ąrì</td>
<td>əndʒe ărì</td>
<td>əndʒe ărì</td>
<td>‘bird’</td>
</tr>
<tr>
<td>ţi</td>
<td>əndʒe .Compose ţi</td>
<td>əndʒe .Compose ţi</td>
<td>‘cow’</td>
</tr>
</tbody>
</table>

2 Shambaa
Propose autosegmental rules to account for the following tone alternations. Note that all infinitives have the final suffix -a.

<table>
<thead>
<tr>
<th>‘to V’</th>
<th>‘to V for’</th>
<th>‘to V e.o.’</th>
<th>‘to V it’</th>
<th>‘to V it for’</th>
</tr>
</thead>
<tbody>
<tr>
<td>kudika</td>
<td>kudikia</td>
<td>kudikana</td>
<td>kut'ıdika</td>
<td>kut'ıdika</td>
</tr>
<tr>
<td>kutoa</td>
<td>kutoana</td>
<td>kutoana</td>
<td>kut'ıtoa</td>
<td>kut'ıtoea</td>
</tr>
<tr>
<td>kuńuntha</td>
<td>kuńunthana</td>
<td>kuńunthana</td>
<td>kuńunthana</td>
<td>kuńunthia</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>‘to V’</th>
<th>‘to V for’</th>
<th>‘to V eat other’</th>
<th>‘to V for eat other’</th>
</tr>
</thead>
<tbody>
<tr>
<td>kukómá</td>
<td>kukóméa</td>
<td>kukóméana</td>
<td>‘kill’</td>
</tr>
<tr>
<td>kufúa</td>
<td>kufúana</td>
<td>kufúana</td>
<td>‘launer’</td>
</tr>
<tr>
<td>kuńija</td>
<td>kuńija</td>
<td>kuńija</td>
<td>‘smear’</td>
</tr>
<tr>
<td>kufúmbátija</td>
<td>kufúmbátija</td>
<td>kufúmbátija</td>
<td>‘pack’</td>
</tr>
</tbody>
</table>

3 Holoholo
Verbs have an infinitive prefix or a subject marker, an optional negative prefix, then an optional object pronoun, and lastly the verb stem. The stem is composed of a root, a number of optional derivational suffixes, plus the morpheme -a which means ‘nonpast verb’ or -ile meaning ‘past.’ Consonant mutation rules can be ignored (e.g. il — in), as well as some of the segmental allomorphs (kuhuuléna from /kuhuulilana/, or kumweená from /kumonila/).
What is important is tone and rules relating to vowel sequences. Assume a principle of compensatory lengthening for the language where glide formation and vowel fusion applying to an underlying V+V sequence lengthen the vowel –/i+o/ becomes [joo].

There are regularities regarding vowel length to consider. There are no surface representations such as *[kuponka], with a short vowel followed by the sequence nasal plus consonant, also no forms like *[kufaka], with short vowel after a glide. Furthermore, no words end in a long vowel.

The data are divided into conceptually related groups illustrating a particular point such as a rule, a particular restriction on a rule, or the surface tone pattern of words of a particular syllabic structure. It is important to integrate the whole data set, and for example to relate kumonàná ‘to see each other’ to kumoná ‘to see,’ and also to kulolana ‘to look at e.o.,’ since kumonàná has morphemes in common with both words.
<table>
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<th>Swahili</th>
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<td>to see</td>
<td>kumona</td>
</tr>
<tr>
<td>to look at</td>
<td>kulola</td>
</tr>
<tr>
<td>to see e.o.</td>
<td>kumonanà</td>
</tr>
<tr>
<td>to look at e.o.</td>
<td>kulolana</td>
</tr>
<tr>
<td>to forge for e.o.</td>
<td>kusiliana</td>
</tr>
<tr>
<td>to listen</td>
<td>kutegeéléla</td>
</tr>
<tr>
<td>to listen to e.o.</td>
<td>kutegeélélanà</td>
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<tr>
<td>to eat</td>
<td>kuljà</td>
</tr>
<tr>
<td>to eat for</td>
<td>kuliila</td>
</tr>
<tr>
<td>to ask</td>
<td>Kubuusjà</td>
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<td>to be bad</td>
<td>Kubihà</td>
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<td>to hit</td>
<td>Kutuuta</td>
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<tr>
<td>to put</td>
<td>Kubiikà</td>
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<tr>
<td>to eat for s.t. for s.t. else</td>
<td>Kuliillà</td>
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<tr>
<td>to bury e.o.</td>
<td>Kusiikana</td>
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<tr>
<td>to listen</td>
<td>Kutegelé</td>
</tr>
<tr>
<td>to listen to</td>
<td>Kutegelélanà</td>
</tr>
<tr>
<td>to eat</td>
<td>Kulja</td>
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<tr>
<td>to carry</td>
<td>Kuhjà</td>
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<td>to suffer</td>
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<td>to clean up</td>
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<td>to kill</td>
<td>Kwiihaja</td>
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<td>to rest</td>
<td>Kooja</td>
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<td>to buy</td>
<td>Kooja</td>
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<td>to wash</td>
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<td>to make disappear</td>
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<td>to make suck</td>
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<td>to make miss</td>
<td>Kubusà</td>
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<tr>
<td>to make miss</td>
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<td>to irritate</td>
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<td>to look at</td>
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<tr>
<td>to listen to them</td>
<td>Kubatégéléla</td>
</tr>
<tr>
<td>to not see</td>
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<td>to not look at</td>
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<td>‘to worry’</td>
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<td>‘to worry oneself’</td>
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<td>kwiiolóla</td>
<td>‘to look at oneself’</td>
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<td>kuula</td>
<td>‘to buy’</td>
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<td>kusjulána</td>
<td>‘to not buy e.o.’</td>
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<tr>
<td>kwita</td>
<td>‘to call’</td>
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<tr>
<td>kusiitá</td>
<td>‘to not look at self’</td>
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**Further reading**

## Glossary

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<td>The elimination of an underlying phoneme in all contexts, so that it always merges with some other phoneme.</td>
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<tr>
<td><strong>acoustics</strong></td>
<td>The study of physical vibrations (sounds).</td>
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<td><strong>affricate</strong></td>
<td>A stop with a homorganic fricative release.</td>
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<tr>
<td><strong>allomorphs</strong></td>
<td>Different surface realizations of a single morpheme, traditionally only considering nonallophonic differences, e.g. the three variants of the English plural [-s], [-z], and [-iz].</td>
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<tr>
<td><strong>allophone</strong></td>
<td>A contentually determined variant of a phoneme: the realization of a phoneme in a specific environment, e.g. [k], [kʰ], [kʲ], [kʰi] in English are allomorphs of the phoneme /k/.</td>
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<tr>
<td><strong>alveolar ridge</strong></td>
<td>The ridge between the back of the teeth and the hard palate.</td>
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<tr>
<td><strong>alveopalatal</strong></td>
<td>A consonant produced by placing the tongue on the hard palate behind the alveolar ridge.</td>
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<tr>
<td><strong>approximant</strong></td>
<td>A sound made with very little constriction, where articulators approximate but do not touch, which produces no turbulence in the airflow.</td>
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<tr>
<td><strong>archiphoneme</strong></td>
<td>A theoretical segment which is only partially specified for phonetic properties, omitting some properties such as voicing or nasality which may be determined by rule.</td>
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<tr>
<td><strong>articulation</strong></td>
<td>The contact of two speech organs, such as the tongue tip and the hard palate.</td>
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<tr>
<td><strong>aspiration</strong></td>
<td>Noise produced by air rushing through the open glottis at the release of a consonant.</td>
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<tr>
<td><strong>assimilation</strong></td>
<td>Making segments be more similar along some dimension.</td>
</tr>
<tr>
<td><strong>association lines</strong></td>
<td>Lines which indicate that two autosegments are in an association relation, thus are produced at the same time.</td>
</tr>
<tr>
<td><strong>bilabial</strong></td>
<td>A sound produced with both lips.</td>
</tr>
<tr>
<td><strong>blade</strong></td>
<td>The flat surface of the tongue, behind the tip and in front of the root.</td>
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<tr>
<td><strong>breathy</strong></td>
<td>A sound produced with abducted vocal folds and a high rate of airflow through the glottis.</td>
</tr>
<tr>
<td><strong>central</strong></td>
<td>A vowel formed with the tongue horizontally positioned in the center of the space for vowel articulation, between front and back (compare mid for the vertical axis).</td>
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<tr>
<td><strong>click</strong></td>
<td>A stop consonant produced by creating a vacuum inside the mouth with a raised back of the tongue and tongue tip or closed lips. Employed in a limited number of African, especially Khoisan, languages.</td>
</tr>
<tr>
<td><strong>coda</strong></td>
<td>The final sequence of consonants in a syllable.</td>
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<td><strong>compensatory lengthening</strong></td>
<td>The lengthening of a segment, caused by the deletion or desyllabification of an adjacent segment.</td>
</tr>
<tr>
<td><strong>complementary distribution</strong></td>
<td>Distribution of two or more sounds where the context in which one sound appears is the complement of the contexts where the other sounds appear.</td>
</tr>
</tbody>
</table>
complex wave | A waveform built from more than one sine wave.
contour tone | A tone produced by movement from one pitch level to another.
contrast | A property of pairs of sounds: two sounds contrast if they can form the sole difference between different words in a language.
coronalization | The change of a noncoronal sound (p, k) to a coronal sound (t, tʃ), usually in the environment of a front vowel or glide.
creaky | An irregular mode of vocal fold vibration where only the front portion vibrates.
dental | A consonant produced by contact with the teeth.
determinant | The segment in the environment which causes a phonological change (also trigger).
diphthong | A combination of two vocoids within the syllable nucleus.
dissimilation | Making two segments become less alike.
distinctive features | A set of phonetic properties, hypothesized to be universal and the basis for all human language sounds.
downstep | A contrastive lowering of tone register, notated with a raised exclamation mark or down-arrow. See upstep.
ejective | A stop consonant produced by raising the larynx with the glottis constricted, which creates pressure in the oral cavity.
environment | The sounds preceding and following some other sound.
epenthesis | Insertion of a segment.
flap | A consonant produced by rapidly striking one articulator with another. Flaps are usually produced with the tongue.
floating tone | A tone which is not associated with a segment.
focus | In a rule, the segment which undergoes the change.
foot | A rhythmic grouping of syllables, relevant for stress systems.
formant | An overtone caused by the resonance frequency of the vocal tract; a frequency band where there is a concentration of acoustic energy.
free variation | A pair of pronunciations, either of which can be used; the choice is not governed by grammatical factors.
frequency | Rate of repetition of a (semi-)periodic function.
fricative | A sound produced by forcing air through a narrow constriction, which creates turbulence.
front | A vowel produced with the tongue horizontally positioned in front of the space for vowel articulation, closest to the mouth opening.
glide | A vowel-like consonant produced with minimal constriction.
glottis | The opening in the larynx between the vocal folds, through which air passes.
hacek | The diacritic symbol ˇ used to indicate rising tone on vowels.
hardening | The change of a less constricted consonant to a more constricted one, such as the change of a glide to a fricative or a stop.
high | Sounds produced with a raised tongue body. For vowels, [i, u] as contrasted with [e, o].
homorganic | Having the same place of articulation.
implicational relation | The relation where presence of one property in a language is a necessary precondition for the presence of some other property.
implosive  A stop consonant formed by creating a vacuum within the mouth, by constricting and lowering the larynx.

labial  A segment involving the lips as an articulator.

larynx  The cartilaginous structure that houses the vocal folds.

lax  Vowel produced with a less deliberate, more central or lower articulation. Comparable to open; contrast tense.

lenition  A change of a consonant to reduce the degree of constriction, e.g. the change from a stop to a fricative or glide.

lexicon  The collection of morphemes which must be memorized: a mental dictionary.

lingual  Pertaining to the tongue.

liquids  Consonants of the type [r, l].

low  Sounds produced with a lowered tongue: vowels like [a, æ] and pharyngeals [h, ʕ].

major class  The set of features [sonorant], [syllabic], [consonantal], or their equivalents.

manner of articulation  Traditionally, the properties of a consonant other than the place of articulation and its laryngeal properties.

markedness  An abstract property referring to the “unusualness” or difficulty of a sound or process.

mid  Vowel sounds such as [e, o] produced with the tongue around the midpoint on the vertical axis: compare central, which pertains to the midpoint along the horizontal axis.

minimal pair  A pair of distinct words differing solely in the choice of a single segment.

mora  A unit of prosodic weight, related to length: a long vowel has two moras and a short vowel has one. The mora may be a property of both a particular segment and an entire syllable.

morpheme  The smallest unit of word analysis, such as a root or affix. Supposedly the smallest meaning-bearing unit, but not all morphemes have identifiable meanings.

morpheme structure rules, conditions  Rules that state the nature of possible underlying forms of morphemes.

morphophonemics  Phonological alternations, especially nonallophonic changes.

nasal  A sound produced with air flowing through the nasal passages.

natural class  A set of segments defined by a particular combination of feature specifications, which act as a group in phonological rules.

neutral position  The position which the tongue assumes prior to speaking, approximately that of [ε]. Used as the reference point to define relative movements of the tongue.

neutralization  Eliminating an underlying distinction between phonemes in some context.

nucleus  The vowels or syllabic segments which form the center of a syllable.

obstruent  A nonsonorant consonant, such as stops and fricatives.

onset  The consonants at the beginning of the syllable which precede the vowel.

onset  The initial sequence of consonants in a syllable.
palatal | Referring to the hard or soft palate. As a primary articulation, a consonant produced at the boundary between the hard and soft palate.

palatalization | Either a secondary articulation made by superimposing a j-like articulation on a consonant, or a wholesale change of a consonant’s place of articulation to alveopalatal (see coronalization).

pharynx | The lower part of the throat.

phonation | The manner of vibration of the vocal folds (modal, breathy, creaky).

phoneme | A mental integration of the different physical properties of the sounds used in a language, abstracting away from specific phonetic properties which are due to the context where the sound appears.

pitch | The percept of rate of vibration.

prenasalization | A sound produced with an initial interval of nasal airflow — often treated as a homorganic cluster of nasal plus consonant.

privative | A feature having only one value: either the feature is present, or not present.

prosody | Properties “above” the segment which pertain to syllabification, length, stress, and rhythm.

retroflex | Consonant articulation involving the tip of the tongue and the back of the alveolar ridge or palate.

reversal of sound change | The historical loss of a phonological rule, which leads to the (partial) restoration of earlier sounds — Yiddish and Ukrainian provide classic examples.

rhyme | A portion of the syllable encompassing the nucleus and coda.

round | A sound produced with protruded lips.

segment | A mental division of the continuous stream of speech into significant permutable units.

semi-vowels | See glide.

spectrogram | A continuous analytic display of acoustic properties of sound over time, showing which frequencies are emphasized at each moment.

spontaneous voicing | Passive vibration of the vocal folds which results from breathing, a characteristic of sonorants. This is brought about by a particular positioning of the vocal folds combined with a relatively unobstructed air passage.

stop | A sound where the flow of air is completely obstructed.

stress | A form of prosodic prominence typically resulting in greater length and higher pitch within the syllable.

structural change | That part of a rule which states in what way a given sound changes.

structure preserving | The property of rules that outputs are modified to preserve the nature of underlying forms, especially in terms of what phonemes exist in the language.

syllable | A unit of speech claimed to be relevant for the organization of words, a grouping of consonants and vowels into a $C_VC_0$ constituent.

syllable peak | The span within the syllable perceived as (capable of) bearing stress.

syncope | Deletion of a vowel in a medial syllable, especially in a fashion that affects alternating syllables.
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<th>Term</th>
<th>Definition</th>
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<td>target</td>
<td>See focus. Vowel produced with a more deliberate and higher articulation.</td>
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<tr>
<td>tense</td>
<td>Vowel produced with a more deliberate and higher articulation. Comparable to close; contrast lax.</td>
</tr>
<tr>
<td>tone</td>
<td>A property based on the contrastive use of pitch.</td>
</tr>
<tr>
<td>translaryngeal harmony</td>
<td>Assimilation of vowels which applies only across laryngeal consonants.</td>
</tr>
<tr>
<td>trigger</td>
<td>See determinant.</td>
</tr>
<tr>
<td>typology</td>
<td>The parametric study of crosslinguistic variation in grammatical structure.</td>
</tr>
<tr>
<td>underlying</td>
<td>Pertaining to the initial state in a phonological derivation; the phonological facts holding of a word or morpheme before phonological rules affect changes.</td>
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<td>upstep</td>
<td>A contrastive raising of tone register, notated with a raised inverted exclamation mark or an up-arrow. See downstep.</td>
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<tr>
<td>uvular</td>
<td>A consonant formed by constricting the back of the throat near the uvula with the back of the tongue.</td>
</tr>
<tr>
<td>velar</td>
<td>A consonant formed by bringing together the back of the tongue and the soft palate.</td>
</tr>
<tr>
<td>velarized</td>
<td>A secondary articulation formed by approximating the back of the tongue towards the soft palate.</td>
</tr>
<tr>
<td>velum</td>
<td>The soft palate.</td>
</tr>
<tr>
<td>vocal folds</td>
<td>Two membranes in the larynx, whose vibration provides voicing and most of the sound energy of speech.</td>
</tr>
<tr>
<td>vocal tract</td>
<td>The air passages above the glottis, including the oral tract and the nasal passages.</td>
</tr>
<tr>
<td>vocoid</td>
<td>A vowel-like sound with no major obstruction: the class of vowels and glides.</td>
</tr>
<tr>
<td>voicing</td>
<td>The presence of vocal fold vibrations during the production of a sound produces voicing.</td>
</tr>
<tr>
<td>vowel harmony</td>
<td>An assimilation between vowels where one vowel takes on the properties of a neighboring vowel.</td>
</tr>
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<td>waveform</td>
<td>A display of the time-varying amplitude of sound pressure.</td>
</tr>
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<td>weakening</td>
<td>See lenition. A property of syllables which may be divided into light and heavy syllables: heavy syllables typically have a long vowel or diphthong, or sometimes a short vowel plus consonant. See mora.</td>
</tr>
<tr>
<td>weight</td>
<td>A property of syllables which may be divided into light and heavy syllables: heavy syllables typically have a long vowel or diphthong, or sometimes a short vowel plus consonant. See mora.</td>
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