CHAPTER 8
Phonological typology and naturalness

PREVIEW

One of the goals of many phonologists is explaining 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

As part of the scientific inquiry into the nature of phonological systems, we want to understand why some facts are unevenly distributed in languages – why similarities and differences in phonologies are not completely random. This is the "null hypothesis", which states that there is no relationship at all between any two variables, and the essence of science is finding out whether there actually is such a relationship. The most powerful such relationship in linguistics is a universal relation, for example A and B never co-occur or always co-occur – in such a case, we may be tempted to build that fact into the theory of language itself. But even if the relationship between A and B is only "nearly universal" – two facts always go together with only a handful of exceptions, or never do with just a few exceptions – an uneven distribution is of interest because we want to understand why the distribution is not 50-50. Finding the cause behind a non-random distribution of facts is the driving force behind scientific research.

In order to explaining *why* certain facts are non-randomly distributed, we have to have a reasonable idea *what* the distributional patterns are. Providing such survey information on language 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 non-random patterns, which form the basis for theorizing about the reason for these patterns.

8.1 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**, 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 which is said to be unmarked, but relatively few have the uvular [q], which is said to be a marked sound. Markedness is a comparative concept, so [q] is more marked than [k] but less marked than [ʕ]. Many languages have the voiced approximant [l], few have the voiceless lateral fricative [ɬ], and even fewer have the voiced lateral fricative [ɮ]. Very many languages have the vowel system [i e a o u]; not many have the vowel system [ɨ œ ʊ ɪ].

Related to frequency of segment types across languages is the concept of **implicational relation**. An example of an implicational relation is the one 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: the existence of nasal vowels implies the existence of oral vowels. All languages have voiced sonorant consonants, and some additionally have voiceless sonorants: no language has only voiceless sonorants. Or, many languages have only a voiceless series of obstruents, others have both voiced and voiceless obstruents; but none have only voiced obstruents.

The method of comparing inventories. Three methodological issues need to be considered when conducting typological studies of inventories. First, determining what is more common versus less common requires a good-sized random sample of the languages of the world. It is invalid to introspect about what sounds exist in the languages that you happen to know and then conclude whether those are relatively "common" sounds in human languages. Phonologists often hunt for grammars of languages to get a broader understanding about what exists in languages. The problem with grammar hunting – which remains the best available tool for typology – is that 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).

Why does it matter what language family or part of the world the sample comes from? The reason is that the properties of a language today are very likely to be highly similar to the properties of the language as spoken in the past. Phonological systems are subject to substantial inertia. Usually, the language learned by a child is almost the same in grammatical details from the language of the previous generation (perhaps not that of the child's parents, in the case of language shift). The exact physical quality of [i, ɪ, æ] in English may randomly change a tiny bit from person to person, but the system of contrasts is very slow to change, for example the vowel merger where originally-distinct "cot" and "caught" are pronounced the same in the US has been going on for over two centuries and is still dialectally incomplete. If a "sample of language sounds" is primarily based on what exists in mainstream English dialects, you will get a distorted view of how common [θ], [ɹ], [ɬ], [q'] and [ʁ] are. Even if you expand the database to all of Indo-European, you would still falsely conclude that [q'] is a non-existent sound in human language, because Proto-Indo-European did not have that segment and nothing caused a daughter language to create that segment from something else.

Second, it is often difficult to determine the true phonetic values of transcriptional symbols in a language which you do not know, therefore one can easily misinterpret a

symbol found in a grammar. We have touched on this problem in Chapter 2, pointing out that even the choice of supposedly standardly-defined symbols as found in the IPA is still subject to considerable interpretive uncertainty. For one thing, very few languages have benefitted from a focused expert phonetic analysis. You will have experienced a level of uncertainty in Chapter 2, in deciding which vowel symbols to assign to particular words in Logoori, and the same can no doubt be said about the choice of consonants. Moreover, language data is typically given in some kind of orthographic form where letter choices are made to radically reduce the orthographic exotica required to represent pronunciations of the language. The preceding chapters have presented a number of examples from Shona with consonants such as [ʃ, ɓ, b, β, v, ʒ, m̩, ŋ, ɖ͡ʐ], but these are spelled respectively [sh, b, bh, v, vh, zh, mh, n', dzv]. Without looking for an explanation of Shona orthography, one might misinterpret the richer actual inventory of consonants for a non-existent rich inventory of consonant clusters. The consonants spelled <p t k> in a language may actually be ejective [p' t' k'], but <p t k> are used in the spelling system because *p, t, k* are "more basic" segments and the author of a grammar may notate ejectives with "more basic" symbols if no plain 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 voiceless aspirated and ejective stops ─ there are no plain unaspirated voiceless stops. The ejectives are simply written <p t k> because there is no need to distinguish [p] and [p']. This phonetic detail may be reported in a footnote in grammars, 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 and they do have ejectives.

Third, most typological claims are statistical rather than absolute – they are statements about what happens most often, and therefore encountering a language which 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.

There is a useful online resource for getting information about inventories, PHOIBLE at https://phoible.org/. The authors have gathered together publically available information about a number of languages including descriptive resources, and collected this into a database, so that you can get some idea how common particular sounds are (e.g. *m* appears at this moment in 2914 languages with is 96% of entries and *bˠ* appears in 1 language, Southern Pumi (Prinmi)). You still have to check the original sources, what PHOIBLE does is tell you where to look.

Typical inventories. With these caveats, here are some general tendencies in 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.

But when a language has only one variety of coronal, that variety may well be phonetically dental or postalveolar.

In terms of manners of consonant articulation, stops are found in all languages. Most language have at least one fricative (though many Australian languages have no fricatives), and the most common (voiceless) fricative is *s*, followed by *f* and *ʃ*, then *x*, then *θ* and other fricatives. The most common affricates are the alveopalatals, then the other coronal affricates; p^f and k^x are noticeably less frequent. In terms of laryngeal properties of consonants, all languages have voiceless consonants (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, most-common 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 [ae œ a ɒ]is quite rare, but it is not hard to find languages with [i y ɨ u]. As noted earlier, oral vowels are more common than nasal vowels, and modal voiced vowels are more common than creaky voiced or breathy vowels.

An interesting fact about segmental inventories is that there are no specific mandatory segments in language. The 12 most common segments in the PHOIBLE database are (in descending order of frequency) are [m i k j u a p w n t l s] appearing in a range from 96% of language entries to 67%. For example even though [m] is the commonest segment in the world's languages, it is not a segment of Lushootseed, Tillamook, Quileyute, Central Rotokas, Tlingit (depending on dialect), Wichita, and most Iroquoian languages such as Mohawk, Oneida, Seneca, Cayuga and Onandaga. The most common vowel, [i], is found in only 2,779 entries (92%). It is inevitable that any (spoken) language will have *some* set of consonants and *some* set of vowels, because without some alternation between consonants and vowels, it would be impractical to signal meaning differences relying just on the poorly audible consonant sequences like [kt] or [sv], or the more-audible but

harder-to-distinguish sequences of vowels [ai], [aoi], [iueaa] or [iueaaaa]. There is little explanatory value in looking at the distribution of single sounds across language, because languages do not sweep together random collections of humanly-possible sounds, instead, they exploit the combinatoric possibilities of different *classes* of sounds, for example by having a class of ejectives (where one can learn the acoustic unity of ejectives thereby multiplying the number of different possible signals of meaning), or a class of retroflex consonants, or distinctive tone, or vowel nasalization.

There remains an unanswered inventory question of considerable theoretical import, one lightly raised in Chapter 4, whether there are "imaginable" but nonexistent sounds in human languages. All human language sounds are produced exclusively with vocal tract anatomy, excluding limbs as speech articulators. There are still quite a number of sounds that can be produced purely in the vocal tract which have yet to be observed in language. For instance, one might describe a consonant formed by raising the tongue and closing the lips then creating a vacuum with the tongue – and asking "does any language have that sound?". As it happens, there is an IPA symbol for representing this, [ʘ], because it is a phoneme in three languages of southern Africa as well as a ritual speech form Damin which used to be used by Yangkaal and Lardil men in Australia. One can imagine various other sounds that can be made with the vocal tract and wonder, "Is *that* a possible human language sound?" (a voiceless rounded pulmonic ingressive uvular trill – an oinking sound, which we could symbolize as 猪). If we happen to find this as a phoneme in some language, we could simply expand our inventory of "possible" sounds. The traditional theory of features makes the prediction that is *not* a possible human language sound, because language sounds are said to be combinations of phonetically-defined features, and the standard set of features does not contain any feature describing inhalation, which is the crucial property distinguishing a uvular fricative [χ] from [猪]. Whether or not the lack of inhaled phonemes needs to be encoded in grammatical theory is highly controversial – or is there some non-grammatical reason for that lack. This question deserves to be carefully scrutinized when making grammatical claims about impossible language sounds.

Given the lack of hard existential universals for inventories, what would constitute an interesting scientific question about inventories? We noted above that languages have more distinct places of articulation amongst stops than they do amongst nasals. Why is that so? There is a non-grammatical functional explanation – see §8.4 for other examples – that because of the acoustic structure of nasals, it is harder to perceive a place difference in nasals than it is to perceive a place difference in stops (the required energy differences are weaker in nasals).

8.2 Segmental processes

Recurrent patterns are also found in rules themselves. Here, there is little controversy over whether there are "impossible rules", lacunae which are properly recognized as systematic and not accidental. This systematicity is encoded in the theory of rules (to the extent that we agree what the theory of rules should be). As an example, we have a mechanism for distinguishing odd-numbered vowels or even-numbered vowels (relying on the notation "$\#(C_0VC_0V)_0\_\_$", and this kind of factoring of a string is linguistically

motivated, given that numerous languages stress or reduce "every other vowel". But other kinds of describable sequences are completely missing from the human language fact database, for instance "stress every vowel in a prime-numbered vowel" or "…in the Fibonacci sequence". No phonological operation produces the mirror-image of a string. Furthermore, such rules cannot be formalized even in the relatively unconstrained notational theory of SPE.

There has been a productive interaction between existential queries ("does such a rule exist?") and formal theorizing about rules – we will explore these developments in later chapters, stemming from the fact that we realized that certain formally-allowed rules are never encountered, therefore it may be that the notation is expressing the wrong generalization. As background to appreciating some of those refinements in formal rule theory, we should first see what kinds of "imaginable rules" actually exist versus do not exist.

We begin our typological survey of rules with segmental rules and procede to prosodic ones. Put roughly, segmental phonology deals with how the features of one segment affect the features of another segment, and prosodic rules 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. Such a division of processes is strictly heuristic given that we have yet to embrace the concept "syllable" at this stage of the book, 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 Chapters 10-11.

8.2.1 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.*

(1)	*Nom sg*	*Gen sg*	*Nom pl*	*Gen pl*	
	ip	ip-in	ip-ler	ip-ler-in	'rope'
	tʃɨkɨʃ	tʃɨkɨʃ-ɨn	tʃɨkɨʃ-lar	tʃɨkɨʃ-lar-ɨn	'exit'
	kɨz	kɨz-in	kɨz-lar	kɨz-lar-in	'girl'
	ev	ev-in	ev-ler	ev-ler-in	'house'
	biber	biber-in	biber-ler	biber-ler-in	'pepper'
	sap	sap-ɨn	sap-lar	sap-lar-ɨn	'stalk'
	adam	adam-ɨn	adam-lar	adam-lar-ɨn	'man'

This process can be stated formally as (2).

(2) $V \rightarrow [\alpha back] / \underset{[\alpha back]}{V} \; C_0 \_$

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-ɨn	'stamp'
	ok	ok-un	ok-lar	ok-lar-ɨn	'arrow'
	son	son-un	son-lar	son-lar-ɨn	'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) $\underset{[+ \text{ high}]}{V \rightarrow} \; [\alpha round] / \underset{[\alpha round]}{V} \; C_0 \_$

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 non-round, since it is never phonetically round, so the most probable hypotheses are /a/ or /e/. For the genitive suffix, any of /i, ɨ, 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 *ɨ*, *y* are significantly more marked (less common) that /i, u/. The same reasoning might lead you to specifically conclude that alternating high vowels are /i/, on the assumption that *i* is less marked than *u*: however, that conclusion regarding markedness is not certain. The validity of invoking segmental markedness for chosing underlying forms is a theoretical assumption, and does not have clear empirical support. A further solution to the problem of picking between underlying forms is that [+high] suffix vowels 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 right now.

Mongolian also has rounding harmony: in this language, only nonhigh vowels undergo the assimilation, and only nonhigh vowels trigger the process.

(5)

Nominative	*Instrumental*	*Accusative*	
de:l	de:l-e:r	de:l-i:g	'coat'
gal	gal-a:r	gal-i:g	'fire'
dy:	dy:-ge:r	dy:-g	'younger brother'
nøxør	nøxør-ø:r	nøxør-i:g	'comrade'
doro:	doro:-go:r	doro:-g	'stirrup'

This rule can be formulated as in (6).

(6) $$V \rightarrow [\alpha round] / \underset{[-\,hi]}{V} \; C_0 \_ \begin{bmatrix} -hi \\ \alpha rd \end{bmatrix}$$

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-lɨɨn* 'father (associative),' *sep-tiin* 'tool (associative)' vs. *oγo-luun* 'child (associative),' *børø-lyyn* 'wolf (associative),' *tynnyk-tyyn* '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 7, 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)

Accusative	*Dative*	
taʃ-tɨ	taʃ-ka	'stone'
iʃ-ti	iʃ-ke	'job'
utʃ-tu	utʃ-ka	'tip'
konok-tu	konok-ko	'guest'
køz-ty	køz-gø	'eye'
yj-ty	yj-gø	'house'

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 unambiguous rounding harmony are genetically or areally related (Mongolian, Kirghiz, Turkish, Sakha). In many languages, vowel rounding can be predicted from backness or vice-versa, therefore a convincing example would have to show at least

partial independence of backness and rounding (as exists in Turkic languages and at least classical Mongolian). In fact, it appears that all examples of harmonic creation of front rounded vowels also involve simultaneous assimilation of backness. The existence of these different kinds of rounding harmony means that phonological theory must at least provide a tool to describe them. Nor is it safe, given our limited database on variation within rounding harmony systems, to make very strong pronouncements about what constitutes "common" versus "rare" patterns of rounding harmony.

Another type of vowel harmony is vowel-height harmony. Such harmony exists in Kuria, where the tense mid vowels *e, o* become *i, u* before a high vowel. Consider (8), illustrating variations in noun prefixes (*omo ~ umu; eme ~ imi; eke ~ ege ~ iki ~ igi; ogo ~ ugu*) conditioned by the vowel to the right:

(8)	omoó-nto	'person'	omo-sáátʃá	'male'
	omo-té	'tree'	omo-góóndo	'plowed field'
	umu-ríísja	'boy'	umu-múra	'young man'
	eme-té	'trees'	imi-sí	'sugar canes'
	ege-sáka	'stream'	ege-té	'chair'
	egeé-nto	'thing'	igi-túúmbe	'stool'
	iki-rúúŋgúuri	'soft porridge'	iki-múúnɛ́	'deer'
	ogo-gábo	'huge basket'	ogo-tábo	'huge book'
	ogo-sééndáno	'huge needle'	ogo-gɛ́na	'huge stone'
	ugu-síri	'huge rope'		

These examples show that tense mid vowels appear before the low vowel *a* and the tense and lax mid vowels *e,* ɛ, *o,* ɔ, which are [-high], and high vowels appear before high vowels, so based just on the phonetic environment where each variant appears, we cannot decide what the underlying value of the prefix is, [-high] or [+high]. Additional data show that the prefixes must underlyingly contain mid vowels: there are also prefixes which contain invariantly [+high] vowels.

(9)	iri-tɔ́ɔ́kɛ	'banana'	iri-kɛ́ɛ́ndɔ	'date fruit'
	iri-hííndi	'corn cob'	iri-tóro	'buttock'
	ibi-góóndo	'small fields'	ibi-gáátɛ	'small breads'
	ibi-gúrúbe	'small pigs'	ibi-té	'chairs'
	itʃi-séésé	'dog'	itʃi-ŋáámwi	'cat'
	itʃi-ŋɔ́ɔ́mbɛ	'cow'	itʃii-ŋgúrúbe	'pig

The alternations in (8) can be described with the rule (10).

(10) $$\begin{matrix} V \\ [+\text{ tense}] \end{matrix} \rightarrow [+\text{ high}]/\_C_0 \begin{matrix} V \\ [+\text{ high}] \end{matrix}$$

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, ɛ, 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 [ɛ ɪ i].

(11)				
	ásim-a	'borrow'	ásim-ilw-a	'be borrowed'
	ín-a	'dance'	ín-ilw-a	'be danced'
	kún-a	'grate coconut'	kún-ilw-a	'be grated'
	ʊ́ʊg-a	'bathe'	ʊ́ʊg-ɪlw-a	'be bathed'
	twíɪk-a	'lift a load'	twíɪk-ɪlw-a	'be lifted'
	bɔ́ɔl-a	'tear bark off a tree'	bɔ́ɔl-ɛlw-a	'be de-barked'
	kɛ́ɛŋgɛɛmb-a	'uproot tubers'	kɛ́ɛŋgɛɛmb-ɛlw-a	'be uprooted'
	tʃáag-a	'grind'	tʃáag-ij-a	'make grind'
	tʃíind^{3}-a	'slaughter'	tʃíind^{3}-ij-a	'make slaughter'
	ʊ́ʊg-a	'bathe'	ʊ́ʊg-ɪj-a	'make bathe'
	bɔ́ɔl-a	'de-bark'	bɔ́ɔl-ɛj-a	'make de-bark'
	tʃɛ́ɛŋg-a	'build'	tʃɛ́ɛŋg-ɛj-a	'make build'

This process involves the complete assimilation of suffix vowels to the values of [hi] 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).

(12) $$\begin{bmatrix} \text{V} \\ -\text{low} \end{bmatrix} \rightarrow \begin{bmatrix} \alpha\text{high} \\ \beta\text{tense} \end{bmatrix} / \quad \begin{bmatrix} -\text{low} \\ \alpha\text{high} \\ \beta\text{tense} \end{bmatrix} C_0 \_$$

Akan exemplifies a type of vowel harmony which is common especially among the languages of Africa, which is assimilation of the feature ATR. In Akan, vowels within the word all agree in their value for [ATR]. In (13a) the prefix vowels are [+ATR] before the [+ATR] vowel of 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	mɪ-dɪ
	2sg	wu-di	wʊ-dɪ
	3sg	o-di	ɔ-dɪ
	1pl	je-di	jɛ-dɪ
	2pl	mu-di	mʊ-dɪ

	3pl	wo-di	wɔ-dɪ	
b.	o-be-di	‘he will eat’	ɔ-bɛ-dɪ	‘he’ll be called’
	o-di-i	‘he ate’	ɔ-dɪ-ɪ	‘he was called’
	o-ko-di	‘he goes and eats’	ɔ-kɔ-dɪ	‘he goes and is called’

Vowel nasalization is also a common assimilatory process affecting vowels, and can be seen in the data of (14) from Gã. These data illlustrate nasalization affecting the plural suffix, which is underlyingly /i/ and assimilates nasality from the immediately preceding vowel.

(14)			
	mlɛɛbo	mlɛɛbo-i	‘liver’
	nãne	nãne-i	‘leg’
	tʃĩĩsi	tʃĩĩsi-i	‘plate’
	akplɔ	akplɔ-i	‘spear’
	gbɛ	gbɛ-i	‘path’
	mĩ	mĩ-ĩ	‘drum’
	sɛ̃	sɛ̃-ĩ	‘throat’
	tũ	tũ-ĩ	‘gun’
	ŋmɔ̃	ŋmɔ̃-ĩ	‘farm’
	lemã	lemã-ĩ	‘ax’

Another kind of vowel harmony, one affecting multiple features, is sometimes termed “place harmony,” an example of which comes from Efik. In Efik, the prefix vowel /ɛ/ (but not /e/) becomes [a] before [a], [ɔ] before [ɔ], [ɛ] before [ɛ], [e] before [e] and [i], and [o] before [o] and [u].

(15)	*3sg*	*3pl*	
	e-di	e-di	‘come’
	ɛ-bɛri	e-bɛri	‘shut’
	a-kaŋ	e-kaŋ	‘deny’
	ɔ-bɔ	e-bɔ	‘take’
	o-kop	e-kop	‘hear’
	o-kut	e-kut	‘see’

This process involves assimilation of all features from the following vowel, except the feature [high].

(16) $\varepsilon \rightarrow \begin{bmatrix} \alpha\text{round} \\ \beta\text{tense} \\ \gamma\text{back} \end{bmatrix} / \_\_ C_0 \begin{bmatrix} V \\ \alpha\text{round} \\ \beta\text{tense} \\ \gamma\text{back} \end{bmatrix}$

Finally, complete vowel harmony where one vowel takes on all features from a neighboring vowel, is found in some languages such as Kolami. This language has a rule of vowel epenthesis which breaks up final consonant clusters and medial clusters of more than two consonants. The inserted vowel harmonizes with the preceding vowel.

(17)	*Stem*	*1sg pres*	*1sg past*	*Imperative*	
	/tum/	tum-atun	tum-tan	tum	'sneeze'
	/agul/	agul-atun	agul-tan	agul	dig'
	/dakap/	dakap-atun	dakap-tan	dakap	'push'
	/katk/	katk-atun	katak-tan	katak	'strike'
	/melg/	melg-atun	meleg-tan	meleg	'shake'
	/kink/	kink-atun	kinik-tan	kinik	'break'

Another example of complete vowel harmony is seen in the following examples of the causative prefix of Klamath, whose vowel completely assimilates to the following vowel.

(18)	sna-batgal	'gets someone up from bed'
	sne-l'e:ml'ema	'makes someone dizzy'
	sno-bo:stgi	'causes something to turn black'
	sni-nklilk'a	'makes dusty"

Complete harmony is unlikely to ever be completely general − all of these examples are restricted in application to specific contexts, such as epenthetic vowels as in Kolami, or vowels of specific affixal morphemes as in Klamath. Another context where total armony 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,' *pʲa-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 articulation of the following consonant.

(19)	*Singular*	*Plural*	
	lwɪ́mo	ɲímo	'land being weeded'
	lwaámbo	ɲaámbo	'bead'
	lweémbe	ɲeémbe	'shaving knife'
	lugolóká	ŋgolóká	'straight'
	lubáu	mbáu	'rib'
	lud^{3}iíŋgjá	ɲd^{3}iíŋgjá	'entered'

lulaála	ndaála	‘pepper’
lupaláaí	mbaláaí	‘bald head’
lutéelá	ndeelá	‘piece of wood’
lutʃwiítʃwi	ɲdʒwiítʃwi	‘tomato’
lukíligo	ŋgilígo	‘place for initiates’
lukíli	ŋgíli	‘palm’

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-bálaaŋgite	m-bálaaŋgite	‘I counted’
		ni-dʒíiŋgiile	ɲ-dʒíiŋgiile	‘I entered’
		ni-góoɲdʒite	ŋ-góoɲdʒite	‘I slept’
	b.	mu-páalite	m-páalite	‘you (pl) wanted’
		mu-téliike	n-téliike	‘you (pl) cooked’
		mu-tʃáawiile	ɲ-tʃáawiile	‘you (pl) ground’
		mu-káatite	ŋ-káatite	‘you (pl) cut’

Sometimes, a language with place assimilation of nasals will restrict the process to a specific place of articulation. For instance, Chukchi assimilates *ŋ* to a following consonant, but does not assimilate *n* or *m*. Thus the stem *teŋ* ‘good’ retains underlying *ŋ* before a vowel, and otherwise assimilates to the following consonant: however, as the last two examples show, *n* and *m* do not assimilate to a following consonant.

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

(21)	teŋ-əɬʔ-ən	‘good’
	tam-waɣərɣ-ən	‘good life’
	tam-pera-k	‘to look good’
	tan-tʃottʃot	‘good pillow’
	tan-ɬəmŋəɬ	‘good story’
	tan-rʔarqə	‘good breastband’
	nə-mkə-kin	‘often’
	ɣa-n-pera-w-ɬen	‘decorated’

A common assimilation affecting consonants after nasals is postvocalic voicing, illustrated 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 *ni.* 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-paláaí	m-baláaí	‘bald head’
lu-tʃwiítʃwi	ɲ-dʒwiítʃwi	‘tomato plant’
lu-téelá	n-deelá	‘piece of wood’
lu-kíligo	ŋ-gilígo	‘initiate’s place’
lu-temá.á	n-demá.á	‘chopped’
lu-tʃapíitʃá	ɲ-dʒapíitʃá	‘clean’

b.

1sg past	*Optional pronunciation*	
ni-páalite	m-báalite	‘I wanted (recent)’
ni-téliike	n-déliike	‘I cooked (recent)’
ni-tʃónite	ɲ-dʒónite	‘I sewed (recent)’
ni-kóbiile	ŋ-góbiile	‘I hit on legs (recent)’

Stop consonants frequently nasalize before nasal consonants, and an example of this process is found in Korean. The examples in (23a) are stems with final nasal consonants; those in (23b) have oral consonants, revealed before the infinitive suffix *a ~ ə*, and undergo nasalization of that consonant before the past-tense suffix *-nɨnta.*

(23)

	Infinitive	*Past*	
a.	an-a	an-nɨnta	‘hug’
	t’atɨm-ə	t’atɨm-nɨntə	‘trim’
	nəm-ə	nəm-nɨnta	‘overflow’
	tʃʰəm-a	tʃʰam-nɨnta	‘endure’
b.	ip-ə	im-nɨnta	‘wear’
	tat-ə	tan-nɨnta	‘close’
	putʰ-ə	pun-nɨnta	‘adhere’
	tʃotʃʰ-a	tʃon-nɨnta	‘follow’
	mək-ə	məŋ-nɨnta	‘eat’
	tak’-a	taŋ-nɨnta	‘polish
	ik-ə	iŋ-nɨnta	‘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-baánda	‘slaves’	m-maánda	‘slaves’
		a-láalo	‘fools’	n-náalo	‘fool’
		a-gúndumúji	‘scarers’	ŋ-ŋúndumúji	‘scarer’
		mi-butúka	‘cars’	m-mutúka	‘car’
		mi-dálaánzi	‘bitter oranges’	n-nálaánzi	‘bitter orange’
		mi-lipú	‘trees (sp.)’	n-nipú	‘tree (sp)’
		mi-gúunda	‘fields’	ŋ-ŋúunda	‘field’
	b.	mu-buundíke	m-muundíke	‘you should store	
		mu-laabúke	n-naabúke	‘you should breakfast’	
		mu-dʒiiŋgí	ɲ-ɲiiŋgí	‘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)	kṛŋʈ-mas	bʰind-mas	1pl indicative active
	kṛŋʈ-e	bʰind-e	1sg indicative middle
	kṛŋʈ-ʈʰa	bʰint-tʰa	2pl indicative active
	kṛŋʈ-ʈe	bʰint-te	3sg indicative middle
	kṛŋɖ-ɖʰve	bʰind-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 shows up as such when attached to a stem ending in a sonorant or voiceless consonant, but after a voiced obstruent, the suffix appears as *-de.*

(26)	smil-e	smil-te	‘smile’	svøm-e	svøm-te	‘swim’
	hør-e	hør-te	‘heard’	lon-e	lon-te	‘borrow’
	les-e	les-te	‘read’	spis-e	spis-te	‘eat’
	reis-e	reis-te	‘travel’	çøp-e	çøp-te	‘buy’
	tenk-e	tenk-te	‘think	behøv-e	behøv-de	‘belong’
	lev-e	lev-de	‘lived’	prøv-e	prøv-de	‘try’
	bygg-e	byg-de	‘build’	hugg-e	hug-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 illustated below with the accusative case suffix /ba/.

(27)

asi:-ba	‘woman’	ŋami:-ba	‘female deer’
palatka-ba	‘tent’	tolgolki:l-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)

	Indefinite	*Definite*		*Indefinite*	*Definite*	
a.	hawa	lhawa	‘air’	ba:red	lba:red	‘cold’
	ʔadham	lʔadham	‘black’	madine	lmadine	‘city’
	ʕa:de	lʕa:de	‘custom’	ha:ra	lha:ra	‘quarter’
	waħʃ	lwaħʃ	‘beast’	jaʔs	ljaʔs	‘despair’
	kalb	lkalb	‘dog’	xadd	lxadd	‘cheek’
	fajj	lfajj	‘shadow’	ɣada	lɣada	‘lunch’
b.	sˤaff	sˤsˤaff	‘row’	ta:let	tta:let	‘third’
	taxt	ttaxt	‘bed’	raʔbe	rraʔbe	‘neck’
	nəde	nnəde	‘dew’	life	llife	‘loofah’
	difa:ʕ	ddifa:ʕ	‘defense’	smike	ssmike	‘thick
	ʃo:raba	ʃʃo:raba	‘soup’	ʒamil	ʒʒamil	‘pretty’
	zaki	zzaki	‘bright’	tˤa:leb	tˤtˤa:leb	‘student’
	zˤa:bet	zˤzˤa:bet	‘officer’	dˤahu:k	dˤdˤahu:k	‘jolly’

Consonants are also often susceptible to assimilation of features from a neighboring vowel, especially place features of a following vowel. One process is palatalization, found in Russian. A consonant followed by a front vowel takes on a palatal secondary articulation from the vowel, as the following data show.

(29)

vkus	‘taste’	vkusʲ-en	‘tasty’
um	‘intellect’	umʲ-en	‘clever’
golot /d/	‘hunger’	golodʲ-en	‘hungry’
stol	‘table’	stolʲ-e	‘table (loc)’

guba	'lip'	gub^{j}-e	'lip (loc)'
mesto	'place'	mest^{j}-e	'place (loc)'
glub-ok	'deep'	glub^{j}-ina	'depth'
ton-ok	'thin'	ton^{j}-ina	'thinness'
vor	'thief	vor^{j}-iska	'thief (pejorative)'
dom	'house'	dom^{j}-iska	'house (pejorative)'
gorot /d/	'town'	gorod^{j}-iska	'town (pejorative)'

The alveopalatal fricatives ʃ, ʒ are not phonetically palatalizable in Russian, whereas the alveopalatal affricate is always palatalized

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)				
	druk /g/	'friend'	druʒ-it^{j}	'to be friends with'
	muka	'torment'	mut^{ʃj}-it^{j}	'to torment'
	gr^{j}ex	'sin'	gr^{j}eʃ-it^{j}	'to sin'
	strok /g/	'strict'	stroʒ-e	'stricter'
	d^{j}ik	'wild'	d^{j}it^{ʃj}-e	'wilder'
	sux	dry'	suʃ-e	'stricter'
	krut	'steep'	krut^{ʃj}-e	'steeper'
	gad-ok	'foul'	gaʒ-e	'fouler'
	vɨs-ok	'tall'	vɨʃ-e	'taller'
	n^{j}iz-ok	'low'	n^{j}iʒ-e	'lower'

Another common vowel-to-consonant effect is affrication of coronal obstruents before high vowels. An example of this is found in Japanese, where /t/ becomes [t^{s}] before [u] and [t^{ʃ}] before [i].

(31)	*Negative*	*Provisional*	*Infinitive*	*Volitional*	
	mat-anai	mat-eba	mat^{s}-u	mat^{ʃ}-itai	'wait'
	tat-anai	tat-eba	tat^{s}-u	tat^{ʃ}-itai	'stand'
	kat-anai	kat-eba	kat^{s}-u	kat^{ʃ}-itai	'win'

Outside of the domain of assimilations in place of articulation, the most common segmental interaction between consonants and vowels (or, sometimes, other sonorants) is **lenition** or **weakening**. Typical examples of lenition 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, ɣ] after vocoids.

(32)	*N*	*with N*	*there are N's*	
	burro	kom burro	aj βurros	'donkey'
	deðo	kon deðo	aj ðeðos	'finger'
	gato	koŋ gato	aj ɣatos	'cat'

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)	*Past affirmative*	*Past negative*	
	tʃaa-βəree	ma-tʃaa-βəree	'go'
	paa-βəree	ma-βaa-βəree	'light'
	pii-βaree	mə-βii-βəree	'renounce'
	kuu-βəree	mə-ɣuu-βəree	'wait'
	kə-βəaree	mə-ɣə-βəree	'hide'
	qɔɔ-βəree	ma-ʁɔɔ-βəree	'take time out'

In some cases, the result of lenition is a glide, so in Axininca Campa, stem-initial /k, p/ become [j, w] after a vowel.

(34)	jaarato	'black bee'	no-jaaratoti	'my black bee'
	kanari	'wild turkey'	no-janariti	'my wild turkey'
	porita	'small hen'	no-woritati	'my small hen'

The converse process, whereby spirants, sonorants, or glides become obstruent stops after consonants, is also found in a number of languages – this process is generally referred to as **hardening**. In 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-jímá	'pole'	ɲ-dʒíma	'poles'
	júkuta	'to be full'	ɲ-dʒukúta	'full'
	wá	'to die'	ŋ-gwaá.á	'dead'
	líndıla	'to guard'	n-dındíılá	'guarded'

Another context where hardening is common is when the consonant is geminate. One example is found in Fula, where geminate spirants become stops. In (36), plural forms

have a medial geminate (this derives by an assimilation to a following *d͡*, so that [tʃabbi] derives from /tʃaw- dɨ/ via the intermediate stage *tʃawwi)*.

(36)	*Plural*	*Diminutive singular*	
	tʃabbi	tʃawel	'stick'
	lebbi	lewel	'month'
	pobbi	powel	'hyena'
	ɲɛbbɛ	ɲewel	'bean'
	leppi	lefel	'ribbon'
	koppi	kofel	'ear'
	tʃoppi	tʃofel	'chick'

Geminate hardening also occurs in Ganda. In the data of (37), the singular form of nouns in this particular class is formed by geminating the initial consonant: the underlying consonant is revealed in the plural.

(37)	*Singular*	*Plural*	
	ggi	ma-gi	'egg'
	ddaala	ma-daala	'ladder'
	dd^{ʒ}uba	ma-juba	'dove'
	gg^{w}aanga	ma-waanga	'nation'
	ddaanga	ma-laanga	'lily'

In this language, only sonorants harden to stops.

(38)	*Singular*	*Plural*	
	ffumu	ma-fumu	'spear'
	ffuumbe	ma-fuumbe	'civet'
	ssaand^{ʒ}a	ma-saand^{ʒ}a	'dry plaintain leaf'
	zzike	ma-zike	'chimpanzee'
	zziga	ma-ziga	'tear'
	vviivi	ma-viivi	'knee'

8.2.2 Dissimilation

Less common in the languages of the world are processes of dissimilation, whereby one of two similar consonants changes to become less like the other. An example of such a process is lateral dissimilation found in Sundanese. In this language, the plural is formed

by infixing *-ar-* after the initial consonant, as seen in (39a). When another *r* follows within the stem, the *r* of the infix dissimilates to *l*.

(39)		*Singular*	*Plural*	
	a.	kusut	k-ar-usut	‘messy’
		poho	p-ar-oho	‘forget’
		gətol	g-ar-ətol	‘diligent’
		ŋoplok	ŋ-ar-oplok	‘flop down’
		ŋuliat	ŋ-ar-uliat	‘stretch’
		tuwaŋ	t-ar-uwaŋ	‘eat’
		masak	m-ar-asak	‘cook’
	b.	ŋɨrɨt	ŋ-al-ɨrɨt	‘cut’
		nugar	n-al-ugar	‘dig up’
		tʃombrek	tʃ-al-ombrek	‘cold’
		botʃor	b-al-otʃor	‘leaking’
		biŋhar	b-al-iŋhar	‘rich’
		hormat	h-al-ormat	‘respect’

A similar process affects the adjectival suffix *-a:lis* in Latin, where /l/ dissimilates to [r] if the preceding stem contains another /l/.

(40)	nava:lis	‘naval’	episcopa:lis	‘episcopal’
	sola:ris	‘solar’	milita:ris	‘military’
	lupana:ris	‘whorish’		

Dissimilation of aspiration is attested in 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)	pi-tʰok	‘give out’	pi-kʰət	‘give upwards’
	cət-tʰok	‘go out’	cət-kʰət	‘go upwards’
	kʰik-tok	‘sprinkle out’	kʰik-kət	‘sprinkle upwards’
	hut-tok	‘bore out’	hut-kət	‘bore upwards’
	kʰoj-dok	‘trim out’	kʰoj-gət	‘trim upwards’
	tʰin-dok	‘pierce out’	tʰin-gət	‘pierce upwards’

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 underlyingly /oko/, as well as the second-singular object prefix /ko/ and the (diminutive) object prefix /ka/. The data in (42a) motivate the underlying prefix /oko/ and (42b) shows application of

dissimilation to the prefix. (42c) shows the object prefixes /ko/ and /ka/ which also dissimilate, and (42d) shows the contrasting prefixes /go/ and /ga/ which have underlyingly voiced consonants, and do not assimilate.

(42)					
	a.	oko-réma	‘to cultivate’	uku-ɲáhaaréka	‘to be hurt’
		uku-míɲooŋgóra	‘to crush	uku-gííŋgírá	‘to shave’
		oko-gɔ́ɔ́gá	‘to slaughter’	uku-búna	‘to break’
		oko-bɔ́tʃa	‘to vomit’	oko-hóóra	‘to thresh’
	b.	ogo-tááŋgá	‘to begin’	ugu-túúhá	‘to be blunt’
		ugu-súraaŋgá	‘to sing praise’	ogo-sɛ́ɛ́nsá	‘to winnow’
		ugu-kjá	‘to dawn’	ogo-kɛ́ɲa	‘to run’
	c.	ogo-kó-bárə̆	‘to count you sg’		
		uku-gú-súraáŋga	‘to praise you sg’		
		ogo-ká-bárə̆	‘to count it’		
		oko-gá-súraáŋga	‘to praise it’		
	d.	oko-gó-bárə̆	‘to count it’	uku-gú-súraáŋga	‘to praise it’
		oko-gá-bárə̆	‘to count them’	oko-gá-súraáŋga	‘to praise them’

The language Chukchi has a number of dissimilatory processes. One of these dissimilates nasality, by changing *ŋ* to *ɣ* before a nasal.

(43)	taraŋ-ək	‘build a dwelling’	nə-tarəɣ-more	‘we built a dwelling’
	mətłəŋ-ən	‘five’	mətłəɣ-more	‘we five’
	enawrəŋ-ək	‘to give as a gift’	enawrəɣ-nen	‘he gave it’
	petʔiŋ	‘cold’	petʔiɣ-ŋinqey	‘boy with a cold’

A second dissimilation in the language changes the first in a sequence of identical fricatives to a stop.

(44)	meniɣ	‘cloth’	manek-ɣəpə	‘from cloth’
	ətłəɣ-ən	‘father’	ətłək-ɣəjiwq-ew	‘paternal marking’
	rəɣrəɣ	‘wool’	rəɣrək-ɣəpə	‘from wool’
	jeɣteł-ək	‘to live’	ɣe-jeɣtet-łin	‘he lived’
	łəmŋəłteł-ək	‘tell stories’	ɣa-łəmŋəłtet-łen	‘told stories’
	ŋew-ʔen	‘woman’	ŋak-waŋe-ɣərɣ-ən	‘woman’s sewing’
	iłɣətew-ək	‘to wash’	iłɣətew-wʔi	‘he washed’

An important feature of this rule is that only homorganic clusters dissimilate. Other combinations, such as *yɣ, wɬ,* or *ɬɣ* remain unchanged.

(45)	kətəjɣat-ək	'blow'	ɣa-n-pera-w-łen	'decorated'
	ʔiw-pipiq-əɬɣ-ən	'wolf mouse'		

Finally the glide *j* dissimilates to **ɣ** before a coronal consonant.

(46)	wʔej-ək	'grass'	wʔeɣ-ti	'grasses'
	ŋin-qej	'boy'	ŋen-qaɣ-tʃəŋ-ən	'big boy'
	tʃaj	'tea'	tʃaɣ-nałk-ək	'to make tea'
	qej-we	'correct'	qeɣ-łənanɣet	'truth
	qəjəqej	'nestling'	qaɣ-jaʔjaq	'young seagull'

Dissimilation between vowels is also found in languages. One case comes from Woleiaian, where the low back vowel /a/ becomes [e] before the low back vowels /a/ and /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-mɒwe	'erase it'	ge-tɒtɒwe	'support it'
	ge-wasir	'hurt it'	ge-tɒla	'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.

8.2.3 Other segmental processes

There are other segmental processes which do not neatly fit into the category of assimilation or dissimilation. One such example is neutralization, whereby a phonetic contrast is deleted in some context, which consonants are particularly susceptible to. One case is the neutralization of laryngeal contrasts in consonants at the end of the syllable, as exemplified by Korean.

(49)	Infinitive	Conjunctive	
	ip-ə	ip-k'o	'wear'
	kap^{h}-a	kap-k'o	'pay back
	tat-ə	tat-k'o	'close'
	put^{h}-ə	put-k'o	'adhere'
	tʃot^{ʃh}-a	tʃot-k'o	'follow'
	mək-ə	mək-k'o	'eat'
	tak'-a	tak-k'o	'polish

Another kind of neutralization is place neutralization, which can be exemplified by Saami, which restricts word-final consonants to the set *t, n, r, l, s, ʃ*, i.e. sonorants and 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'
	tʃoarvvuʃ	tʃoarvvuʃ-in	'antlers and skullcap'
	gahpir	gahpir-in	'cap'
	heeveměahhtun	heeveměahhtun-in	'inappropriate'
	varit	varih-in	'2-year-old reindeer buck'
	tʃuojvvat	tʃuojvvag-in	'yellow-brown reindeer'
	ahhkut	ahhkub-in	'grandchild of woman'
	lottæ:ʃ	lottæ:d^{ʒ}-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 neutralization of laryngeal contrasts.

8.3 Prosodically based processes

A second major class of phonological processes can be termed "prosodically motivated processes." Such processes have an effect on the structure of the syllable (or higher

prosodic units such as the "foot"), usually by inserting or deleting a consonant, or changing the status of a segment from vowel to consonant or vice versa.

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.

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 combination of morphemes, one of the vowels is often changed. One of the most common such changes is glide formation, whereby a high vowel becomes a glide before another vowel. Quite often, this process is accompanied with a lengthening of the surviving vowel, a phenomenon known as compensatory lengthening. For example, in Matumbi, 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-kuŋuúnda	'filtered beer'	lj-oowá	'beehive'
	ki-kálaaŋgo	'frying pan'	kj-uúlá	'frog'
	i-kálaaŋgo	'frying pans'	j-uúlá	'frogs'
	lu-toóndwa	'star'	lw-aaté	'banana hand'
	ku-suúle	'to school'	kw-iisíwá	'to the islands'
	mu-kikálaaŋgo	'in the frying pan'	mw-iikálaaŋgo	'in the frying pans'

Although the stem-initial vowel is long on the surface in these examples, underlyingly the vowel is short, as shown when the stem has no prefix or when the prefix vowel is *a*. Thus, compare *ka-ótó* 'little fire,' *ma-owá* 'beehives,' *ka-úlá* little frog,' *até* 'banana hands,' *ipʊkʊ́* '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).

In Matuumbi, coalescence only applies in a specific grammatical domain, between vowels of prefixes, and thus one does not find this same process affecting the prefix-plus-stem combination found in ka-úlá ' little frog.'

(52)	a-i-téliike	ee-téliike	'he cooked them'
	pa-ú-kaátité	poó-kaátité	'when you cut'
	pa-bá-i-káatité	pa-bée-káatité	'when they cut them'
	a-u-káatite	oo-káatite	'he cut it'

ka-u-tʊʊmbóka	koo-tʊʊmbóka	‘when it was falling’
pa-i-taábu	pee-taábu	‘where the books are’
pa-u-títili	poo-títili	‘where the chicken louse is’
ka-u-méjá	kooméjá	‘little white ant’
na-u-tʃaápu	noo-tʃaápu	‘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 *lipeeta engaanga* → *lipeet engaanga* ‘the knapsack, cut it!’, *likuka engaanga* → *likuk engaanga* ‘the trunk, cut it!’, *nneemba idanaao* → *nneemb idanaao* ‘the boy bring him!’.

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.

(53)	*Continuous*	*Causative*	
	hula	hulna	‘laugh’
	jara	jarna	‘drink’
	woja	wojna	‘cry’
	dʒu:la	dʒu:lna	‘be Muslim’
	wurto	wurtina	‘come out’
	wuddʒa	wuddʒina	‘steal’
	jotto	jottina	‘arrive’

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)		*Infinitive*	*Past*		*Infinitive*	*Past*	
	a.	hàm-à	hám	‘yawn’	ɗàn-à	ɗàn	‘tie’
		skwàl-à	skwál	‘want’	vèr-à	vèr	‘fly’
		ləhàj-à	ləhàj	‘fear’	làw-à	làw	‘fight’
	b.	gəɓ-à	gəɓə	‘answer’	kàɗ-à	káɗə	‘cross’

làb-à	làbə̀	‘tell’	dʒ́àg-à	dʒ́àgə́	‘cook’
gìtʃ́-à	gìtʃ́ə̀	‘sweep’	ʔə̀k-à	ʔə̀kə́	‘take by force’
sàp-à	sapə̀	‘chase’	vìt-à	vìtə́	‘blow on a fire’
vənàh-à	vənàhə̀	‘vomit’	hə̀s-à	hə́sə́	‘spill’
ɗə̂v-à	ɗə̂və̀	‘put’	bàɣ-à	bàɣə́	‘split wood’

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 *í* only when it is attached to a monosyllabic stem.

(55)	k-atirút-haʔ	‘I pull it’
	k-ataʔkeráhkwaʔ	‘I float’
	k-kétskw-as	‘I raise it’
	k-hní:nus	‘I buy’
	k-tat-s → íktats	‘I offer it’
	k-jʌ-s → íkjʌs	‘I put it’
	k-ket-s → íkkets	‘I scrape it’

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)	*Saami*	*Norwegian*	
	da:jgi	deig	‘dough’
	nijbi	kniv	‘knife’
	vowʔnɑ	vogn	‘wagon’
	muwrɑ	mur	‘wall’

In contrast, in the following loanwords there is no epenthetic vowel. The location of stress, which is the key to understanding this problem, is marked on the Norwegian source though stress is not marked in the orthography.

(57)	*Saami*	*Norwegian*	
	di:sdɑt	ˈtirsdag	‘Tuesday’
	ka:wrret	ˈkavring	‘rusk’

akaðemihkɑr	akaˈdemiker	‘academic’
mini:stɑr	miˈnister	‘minister’
teahter	teˈater	‘theater’
temhpel	ˈtempel	‘temple’
orgel	ˈorgel	‘organ’
profes:sor	proˈfessor	‘professor’
pla:stɑr	ˈplaster	‘plaster’
ka:hkɑl	ˈkakkel	‘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:llɑ	hoˈtel	‘hotel’
	mɑrɑto:nɑ	maraˈton	‘marathon’
	universite:htɑ	universiˈtet	‘university’
	tɑbeal:lɑ	taˈbell	‘(time-)table’
	priva:htɑ	priˈvat	‘private’
	kɑme:lɑ	kaˈmel	‘camel’
	pola:rɑ	poˈlar	‘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]õdee	‘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)	*Imperative*	*Conjunctive*	*Indicative*	
	palp-a	pal-k'o	pal-t'a	'tread on'
	ulph-ə	ul-k'o	ul-t'a	'chant'
	ilk-ə	il-k'o	il-t'a	'read'
	halth-a	hal-k'o	hal-t'a	'taste'
	talm-a	tam-k'o	tam-t'a	'resemble'
	anc-a	an-k'o	an-t'a	'sit down'

Another cause of cluster simplification is the avoidance of certain specific types of consonant clusters. Shona avoids clusters of the form 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)	'this'	'my'	Class
	u-no	w-angu	3
	mu-no	mw-angu	18
	ku-no	kw-angu	17
	ru-no	rw-angu	11
	i-no	j-angu	9
	ri-no	r-angu	6
	$t^{ʃ}$i-no	$t^{ʃ}$-angu	7
	z^{w}i-no	z^{w}-angu	8
	d^{z}i-no	d^{z}-angu	10

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)	kú-ˈlíím-a	'to cultivate'
	kú-líˈm-ííl-a	'to cultivate for'
	kú-líˈm-ááán-a	'to cultivate each other'
	kú-lím-áˈn-ííl-a	'to cultivate for each other'

kú-lím-án-íl-á-lím-áˈn-íil-a ‘to cultivate for each other continuously’

A related process is the reduction of unstressed vowels, as found in English. From alternations like *bəˈrɔmətɹ ~ ˌbɛrəˈmɛtrɪk, ˈmɔnəpowl ~ məˈnɔpəlij,* 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)	/goroˈd-ok/ → [gəraˈdok]	‘cities’	/ˈgorod/ → [ˈgorəd]	‘city’
	/ˈpoda-l/ → [ˈpodəl]	‘he gave’	/po-ˈda-tʲ/ → [paˈdatʲ]	‘to give’

Reduction of unstressed vowels can go all the way to deletion, so in Palestinian Arabic, unstressed high vowels in an open sylable are deleted.

(64) *Palestinian Arabic*

3sg masc	3sg fem	1sg	
ˈħamal	ˈħamalat	ħaˈmalt	‘carry’
ˈkatab	ˈkatabat	kaˈtabt	‘write’
ˈdaras	ˈdarasat	daˈrast	‘study’
ˈʃirib	ˈʃirbat	ˈʃribt	‘drink’
ˈnizil	ˈnizlat	ˈnzilt	‘descend’
ˈfihim	ˈfihmat	ˈfhimt	‘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/	ʂaphin	ʂapk’a	ʂa:pal	ʂa: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)	ˈtiralk	‘saliva’	ˈmere˛pet	‘beard’
	ˈjangar˛mata	‘the Pleaiades’	ˈlangka˛rate˛i	‘prawn’
	ˈwele˛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)	wuˈle	‘tomorrow’
	ʈiˈpanto	‘year’
	eˈlumu˛ju	‘give us’
	eˈlua˛enew	‘he will give me’
	kiˈmuba˛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)	ŋinˈtip	‘bee’
	˛kuliˈpu	‘hair of arm’
	u˛luaˈmit	‘mist’
	˛aku˛neteˈpal	‘times’

Finally Warao places the main stress on the penultimate syllable and has secondary stresses on alternating syllables before.

(69)	ji˛waraˈnae	‘he finished it’
	˛japu˛ruki˛taneˈhase	‘verily to climb’
	e˛naho˛roa˛hakuˈtai	‘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)	radˈjoo	‘radio’	qaˈreet	‘I read’
	kaˈtabt	‘I wrote’	ˈqara	‘he read’
	ˈqarat	‘she read’	kaˈtabna	‘we wrote’
	qaˈreethum	‘I read them’	ˈkatabu	‘they wrote’

ˈkatabat ‘she wrote’ ma kataˈbatʃ ‘she didn’t write’

8.4 Why do things happen?

As discussed at the beginning of this chapter, two of the central questions which phonological theory has sought answers to are “why does rule X exist?” and “can rule Y exist?”. Very many languages have a process changing velars into alveopalatals (k → $t^{ʃ}$) 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, ʃ}. By contrasting attested with imaginable but unattested phenomena, typological studies become of scientific interest by calling for an explanation for the observational gap.

Impossible rules. The crosslinguistic study of rule properties has long assisted researchers in developing a formal theory of rules, since a theory of rules at a minimum must correctly say “This can be a rule” or “This cannot be a rule”. Typological studies further subdivide this two-way distinction into a many-way functionally defined collection of “types”, hoping to gain a more fine-grained understanding of what exists versus does not exist in phonology.

The dominant logic of this inquiry is that the answer to the question “What can / cannot be a rule?” should somehow be encoded into grammatical theory. In the grammatical theory employed here, this is done by defining the representational primitives (the features) and the metarules for constructing rules which compute input-output relations in a grammar. Obviously, if we are comparing two theories one of which has a feature called “spread glottis” where [t^h] is [+spread glottis], the other of which has a feature called “aspirated” where [t^h] is [+aspirated], then [+coronal, -continuant] → [+spread glottis] is a possible rule in the former theory but not in the latter. Yet we do not conclude that the two theories are empirically different because they allow / forbid different classes of rules. Given that “spread glottis” and “aspirated” refer to the same real-world fact, differing only in the name assigned to a single concept (similar to the existence of multiple names for the same piece of furniture: sofa, couch, davenport), we would say that the “two” theories are really one theory with multiple expressions of the theory: the theories are **notational variants** of each other. Our ability to identify this essential sameness comes from the fact that we have tools allowing us to talk about the perceptible facts of language separate from how we talk about theoretical analysis, by referring to sets of phonetically-defined symbols. This is obvious above because you understood the essential sameness of [+coronal, -continuant, +aspirated] and [+coronal, -continuant, +spread glottis] via the total identity of the transcription [t^h] which is what these two feature-expresstions refer to. Of course, sameness / difference of letters is not what makes the sounds referred to by feature expressions “essentially identical”, that comes from the fact of following a specific convention such as the IPA for relating features to language sounds. There exist other transcriptional conventions, where IPA [ʃ] is rendered as [š]

(and is so spelled in a number of languages), yet [š] and [ʃ] still refer to the same phonetic thing (though [š] could also refer to "[s] with rising tone" in IPA).

When talking about possible versus impossible rules, we typically employ sets of transcriptional symbols from the IPA to refer to the "meaning" of a rule term. The velar consonants of English, conventionally understood, are {k, k^h, g, ŋ} independent of one's theory of phonological features, and a rule palatalizing velars before high front vowels performs the computation {k, k^h, g, ŋ} → {k^j, k^{hj}, g^j, $ŋ^j$} / __ {i, ɪ}, regardless of one's theory of rule notation. When we investigate the notion "possible rule" in phonology, we are referring to the possibility of expressing a particular set-to-set mapping as a formal phonological expression. Whereas the above velar palatalization is indeed a formalizable (possible) rule in all theories of phonology, the mapping {s, m} → {l, k}/ _{w, ʃ} is not possible (formalizable) in any theory. This is because the informal symbol distinctions {s, m}, {w, ʃ} do not refer to any conjunction of features (which are the primitives of rule statements) and the input-output mapping denoted as "→{l, k}" does not correspond to any conjunctive change in the properties of the input (pseudo-)class {s, m}.

We can take the preliminary null hypothesis for the theory of rule-statements to be "we expect any mapping from a set of IPA symbols to any other sequence of IPA symbols with the same number of members, in a context defined as any number of disjunctions of IPA symbols". This includes as possible rules {k, k^h, g, ŋ} → {k^j, k^{hj}, g^j, $ŋ^j$} / __ {i, ɪ}, {s, m} → {l, k}/ _{w, ʃ}, {s, p} → {q, r}/ {b, a} _{l, o, n, i} and a huge number of other segment-mappings that are imaginable rules, to be distinguished as "possible" versus "impossible". It precludes expressions like {k, k^h, g, ŋ} → {k^j, k^{hj}, g^j, $ŋ^j$, γ, φ} / __ {i, ɪ} because the number of elements in the input and output sets are not the same (basically, such a rule is meaningless).

> *This number of such rules has never been calculated, partly because the common ground of theories changes rather rapidly, and partly because phonologists aren't usually concerned with combinatorics.*

The significance of the lack of {s, m} → {l, k}/ _{w, ʃ} is not this specific non-attestation, it is the large class which it is an example of – a class that includes {s, p} → {q, r}/ {b, a} _{l, o, n, i}, and the overwhelming majority of the mappings covered by the null hypothesis. The theory of features and rules presented to this point in the book does a good job of sorting the set of imaginable mappings into "possible" versus "impossible" subsets on formal grounds.

Yet we are not entirely satisfied with that theory, because it evaluates as "possible" classes of rules which do not exist, thus we say that the theory **over-generates**, it predicts the existence of large sets of rules that have not been seen. This is a kind of false prediction, and when a scientific theory makes a false prediction, we are naturally concerned. The concern is not over the fact that we have not observed all of the possibilities predicted by a theory, it is over the question whether the underlying concepts of the theory are correct, and perhaps a different conceptualization would make better empirical predictions. In aid of understanding this concern, consider rules that would underlying the two sets of segment mappings in (71).

(71) a. $mt^{\int} \rightarrow ɲt^{\int}$ $ŋt^{\int} \rightarrow ɲt^{\int}$

$ɲp \rightarrow mp$ $np \rightarrow mp$

$ɲk \rightarrow ŋk$ $nk \rightarrow ŋk$

$ɲt \rightarrow nt$ $nt^{\int} \rightarrow ɲt^{\int}$

b. $mt^{\int} \rightarrow nt^{\int}$ (not $ɲt^{\int}$) $ŋt^{\int} \rightarrow ɲt^{\int}$

$ɲp \rightarrow ɴp$ $np \rightarrow mp$

$ɲk \rightarrow ŋk$ $nk \rightarrow m^{ɣ}k$

$ɲt \rightarrow ɲt$ $nt^{\int} \rightarrow nt^{\int}$

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 pattern (b), we may ask "why is this pattern unattested?". Both sets correspond to formally-possible rules in the present theory of rules. (71a) is generated by (72a) and (71b) is generated by (72b).

(72) a. $[+\text{nasal}] \rightarrow \begin{bmatrix} \alpha\text{cor} \\ \beta\text{ant} \\ \gamma\text{hi} \\ \delta\text{back} \end{bmatrix} / \_\_ \begin{bmatrix} +\text{cons} \\ \alpha\text{cor} \\ \beta\text{ant} \\ \gamma\text{hi} \\ \delta\text{back} \end{bmatrix}$

b. $[+\text{nasal}] \rightarrow \begin{bmatrix} \alpha\text{cor} \\ \gamma\text{hi} \\ \delta\text{back} \end{bmatrix} / \_\_ \begin{bmatrix} +\text{cons} \\ \alpha\text{cor} \\ \gamma\text{hi} \\ \delta\text{back} \end{bmatrix}$

We cannot explain why (72b) does not exist based just on formal considerations of formally possible rules, at least given the present formal theory. Then do we conclude that this is merely an accidental gap in knowledge, or should we seek a more general explanation? Typological investigation helps us reject the "accidental gap" response, since nasal place assimilation is an extremely common rule in language, and being a very frequent rule we *should* have observed (72b) by now, if there is no other explanatory factor for the gap. After some head-scratching, we recognize a pattern to this and similar gaps, that (72a) assimilates all members of the set of place of articulation features, but (72b) assimilates just a subset of those features, leaving out [anterior]. This leads towards a broad generalization about what sets of features can "act together" in a rule. We discuss how that is implemented in the non-linear theory of representations in Chapter 10, the important point here is that typological studies can lead us to discover lacunae in rules, which may then lead to changes in the formal theory of rules.

Unlikely rules. Now consider a rule /p/ → [$t^{\int}$]/ _{i, e}, which seems hardly different from /k/ → [$t^{\int}$]/ _{i, e}, except that the latter is commonly encountered, and the former is apparently not found in any language. Again we wonder whether this is an attestation gap, or is this also a sign that we need an improved theory of rule statement. Unlike the fragmentary feature assimilation required for (72b), there is no formal characteristic

behind the process "becomes an alveopalatal affricate" which makes a labial be an unsuitable target for a rule, in fact as we will see below, labials can become alveopalatals via a dissimilation process. Should this fact therefore be relegated to the trash heap of "accidental gaps"? The specific gap being considered at the moment is the rule /p/ → [tʃ]/ _{i, e}, however the same non-existence problem arises for similar rules like {p} → {tʃ}/ _{i}, {p, b} → {tʃ, dʒ}/ _i, {p} → {tʃ}/ _{i, e, æ} and {p, f, b} → {tʃ, ʃ, dʒ}/ _{i, e, æ}. They have in common that they change a labial to an alveopalatal before a font vowel, almost the same description as would be applied to common velar coronalization. The entire class of such rules seems to be lacking, and this is regularity which cannot be easily dismissed. But it is not necessarily part of the theory of phonology.

Besides modifying the theory of grammar in some way, we might find an explanation outside of phonological theory. 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 autonomous "law of biology" that ear size should be directly correlated with typical ambient air temperature, but the observation makes sense given a little knowledge of the physics of heat radiation and the structure of ears. In a nutshell, one loses a lot of body heat from big ears, which is a good thing in the desert and a bad thing in the arctic. Perhaps there is an explanation outside of the domain of grammar for the lack of labial coronalization in the set of attested rules. The first step towards gaining that explanation is to try to understand why very many languages have a phonological rule changing velars into alveopalatals before front vowels (in Mwera and related Bantu languages; most Slavic and Romance languages) or before high front vowels (Lamba: see 5.2.1). The initial cause for developing a rule k→tʃ is a similar process found in very many languages, though often under-reported: velar fronting, where /k/ → [kʲ] before front vowels. This happens in English (in *keep, kick, cake, kept* /k/ is fronted to [kʲ], compared to *cool, cook, coat, cot, caught, cup* with velar [k]), and likewise in Turkish, Greek, Catalan, the velar consonants /k, g/ are fronted before front vowels.

The reason for this tendency is physiology. Canonical velars have a further-back tongue position, but front vowels have a further-front tongue position. To produce [ki], with fully-back [k] and fully-front [i], the tongue body would have to quickly move forward a considerable distance. The tongue body is relatively massive and moves slowly, so some articulatory compromise between these contradictory states (dorsal for [k] and palatal for [i]) is required. The compromise reached in most languages is that the tongue targets a further-forward position for [k], sacrificing the backness of [k] in favor of the frontness of [i]. This results in a palatalized velar, i.e. the output [kʲi], which gives us languages like English and Turkish.

This relatively small physiological change of tongue-fronting has a disproportionate effect on the acoustic output. Plain [k] without palatalization (e.g. *k* said by itself) sounds closer to [p] than it does to [kʲ]. Like [p], [k] has a relatively lower formant frequency for the consonant release burst. In comparison [kʲ] sounds more like [t] or [tʃ] (in having a higher burst frequency) than it sounds like [k], to which it is articulatorily more similar (it is still produced with a raised tongue body). The acoustic similarity between alveopalatals like [tʃ] and palatals like [kʲ] is substantial enough that it is easy to confuse

one for the other. Thus a child learning a language may easily (mis)interpret a phonetic alternation [k] ~ [kʲ] as the alternation [k] ~ [tʃ]. Such learning errors in phonetic processing can lead to a historical change in the phonological system, via the addition of a phonological rule (velar coronalization, as found in Lamba, Mwera, Slavic and so on).

Explaining why k → tʃ/ _{i, e} *does* exist is a first step in understanding the lack of attestation of labial coronalization before front vowels. The next question is whether there are analogous circumstances under which unattested labial coronalization rules might also come into existence. Since the production of [p] and [i] involve totally different articulators, no major adjustments to the production of [p] are needed to resolve an articulatory conflict with the forward tongue position of [i]. Production of [p] and [i] can safely overlap without distorting the acoustic structure of either the consonant or the vowel.

> *You are presumably aware that the identity of prevocalic consonants is phonetically made by the effect of the particular consonant on the formants at the beginning of the following vowel.*

The small degree of palatalization found on a labial before a front vowel is not acoustically similar to [kʲ] or [tʃ], and the consonant release of /p/ before /i/ remains at a relatively low frequency.

Another factor encouraging k-coronalization over p-coronalization is the size of the palatal constriction associated with /pi/ versus /ki/. In the case of /ki/, the palatal region is completely obstructed, so even when /k/ is released, this high degree of constriction results in substantial noise with palatal-like resonances owing to the rapid flow of air through a very narrow channel. This means that the palatal release of /ki/ becomes more prominent, influencing perception in the direction of a palatal rather than a velar. In the case of /pi/, there is no significant constriction in the palatal region coming from the consonant, just a smaller degree of narrowing required for producing /i/. Because the constriction in the palatal region after /p/ is negligible, there will not be a palatal-fricative coloring to the consonant release leading to the percept of a ç- or ʃ-like release on the consonant.

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] that a more [ʃ]-like release will result, but this will not happen simply as a response to a small physically motivated change as it does with /k/, it requires some kind of extra-special mechanism to general a palatal release. Thus the probability of a change p → tʃ coming about by simple phonetic mechanisms is very small – but not zero – 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.

There is some historical linguistic evidence that such a rule could in principle be found in a phonology. Bantu languages generally have 7 vowels, along the lines of the Logoori system encountered in previous chapters. The exact phonetic characteristics of the vowels varies from language to language, tending to be [i ɪ ɛ a ɔ ʊ u] in the languages of the eastern zone which retain all 7 of the original vowels (otherwise, [i e ɛ a ɔ o u]). In a

number of Bantu languages, the vowels [i, u] are phonetically "superhigh", produced with greater than usual constriction often notated as [i̝, u̝]. As noted in Chapter 2, the physical range of vowels transcribed as [i, u] can vary substantially depending on the phonetic rules of the particular language, therefore in a language like Lomwe with an extra-high version of these vowels we would still treat them as high vowels at the extreme end of the constriction range for high vowels. This extra-raising may be a compensatory change to increase the acoustic difference between [i u] and [ɪ ʊ] which are often hard to tell apart (as in Logoori).

The so-called superhigh vowels are implicated in a widespread sound change in Bantu, "Spirantization", where original *di → zi but *dɪ → lɪ; *bu → vu but *bʊ → bʊ.

Interestingly, the Spirantization change always seems to be paired with a merger of the two sub-types of high vowel into just [i, u].

In Shona dialects, this resulted in a kind of labial-coronalization change, where the original Class 19 noun prefix *pi became [ʂ^{w}i] and the Class 8 prefix *bi became [ʐ^{w}i] ([ʂ^{w}, ʐ^{w}] are "whistling fricatives", unique phonemes for which there is no IPA symbol – partially retracted alveolars with slight lip protrusion, distinct from [ʃ, ʒ] in the language). This is a purely historical relation between vowel and consonant, not an active part of the modern language. Although this is a multi-generational result of a number of phonetic changes and not the product of a single synchronic rule /pi/→[ʂ^{w}i], it does show that the conjectured path for labial-coronalization can be found and in principle could lead to such a rule in a grammar.

There has been a tendency in phonological thinking to equate "phonetically motivated" with "computationally possible", perhaps on the grounds that most phonological rules can be given functional phonetic explanations for their existence. The germ of truth in this idea is that all phonological rules are the historical product of historical extensions and reanalyses of articulatory changes interacting with perception over generations. Although phonetically unnatural rules are not common in grammars, they do uncontroversially arise in phonological system via appopriate chains of historical change. An example of a synchronic phonetically unnatural process is a delabialization rule in the Nguni subgroup of Bantu languages (Zulu, Xhosa, Swati, Ndebele), where labials become alveopalatals before *w*. We see this alternation in the active versus passive forms of verbs in Swati, with the passive suffix -*w*-.

(73)

Active	*Passive*	
kú-k^{h}ándiŋ-a	kú-k^{h}ándíŋ-w-a	'dry roast'
kú-káp^{h}-a	kú-káʃ-w-a	'chop'
kú-k^{x}éb^{h}-a	kú-k^{x}éd^{3}w-a	'scrape'
kú-lúm-a	kú-lúɲ-w-a	'bite'
kú-nwáb-a	kú-nwát^{ʃ}-w-a	'bury'

Labials have a low formant frequency, and rounding lowers formant frequency, so as pointed out by Ohala (1978) this is a phonetically odd synchronic alternation. We would expect rounding to reinforce labiality. The diachronic situation shows that this state of

affairs results from multiple intersecting phonetic tendencies which cumulatively phonologized as a rule labial → palatal / __ [w]. In a number of Bantu languages of eastern and southern Africa, /w/ causes velarization of the preceding consonant (/w/ is a labio**velar** glide), a process which we have seen in Shona in Chapter 6. In Shona, as well as Kinyarwanda and optionally in Logoori, there is an unrounding process whereby the rounding on the voiceless velar fricative release of /tap-w-a/ 'captured' – otherwise predicted to be [tap^{xw}a] – is eliminated, thus pronounced as [tap^{x}a]. The phonetic realization of this hardened-glide release varies across languages, tending to shift forward, generally appearing variably as [p^{ʃ}] or [t^{ʃ}] in Tsonga and the Sotho-Tswana languages, and ending up as [t^{ʃ}] in the Nguni group. What seems like a quite radical change, given just the underlying-to-surface relation /p/ → [t^{ʃ}] in Nguni, is just the accumulated result of a number of fortuitously combined, less radical steps.

Another famous phonetically unnatural rule is post-nasal devoicing, the opposite of the wide-spread postnasal voicing process. Observe that [b d ɟ] at the beginning of a verb root in the first data column below becomes [p t c] after a nasal in the second column (data from Solé, Hyman & Monaka 2009, from the Shekgalagadi dialect within the broad group).

(74)				
	χʊ-pak-a	'to praise'	χʊ-m-pak-a	'to praise me'
	χʊ-tʊt-a	'to respect'	χʊ-n-tʊt-a	'to respect me'
	χʊ-cób-á	'to beat'	χʊ-ɲ-cób-á	'to beat me'
	χʊ-kɛl-a	'to show'	χʊ-ŋ-kɛl-a	'to show me'
	χʊ-bɔ́n-á	'to see'	χʊ-m-pɔ́n-á	'to see me'
	χʊ-dʊʒ-a	'to annoint'	χʊ-n-tʊʒ-a	'to annoint me'
	χʊ-ɟís-a	'to feed'	χʊ-ɲ-cís-a	'to feed me'

The explanation for the current state of affairs comes from understanding the historical source of the voiced stops – they derive from voiced fricatives (this is discussed more in the final chapter). The post-nasal change of fricative to stop – hardening – is a common process, as discussed above. The original alternation was *χʊβɔ́ná ~ χʊmbɔ́ná*, followed by another sound change devoicing of voiceless stops (*χʊβɔ́ná ~ χʊmpɔ́ná*), followed in turn by hardening of voiced fricatives to stops giving the current situation. This is an unlikely combination of events, but not impossible.

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, perceptability, and confusability, and issues pertaining to communicative function. Virtually every imaginable position on this question has been espoused, and it is certain that the formalist/functionalist debate will persist unresolved for decades.

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

Greenberg 1978; Hale and Reiss 2006, Hayes, Kirchner & Steriade 2004; Maddiesson 1984, Odden 2013.