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Typology, cross-linguistic comparison, markedness, functional explanation.

Phonological Typology and Naturalness

One of the main goals of many phonologist is to explain why certain phonological patterns are found in many languages, while other patterns are found in few or no languages. This chapter looks at the phonological typology — the study of common vs. common, natural vs. unnatural phonological rules, and looks at some of these commonly occurring phonological properties.

A 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 occurs more often across languages. As a prerequisite to explaining *why* some processes are common, uncommon, or even unattested, you need an idea of *what* these common patterns are, and providing this information is the domain of **typology**. While only a very small fraction of the roughly 7,000 languages spoken in the world have been studied in a way that yields useful information for phonological typology, crosslinguistic studies have revealed many recurrent patterns, which form the basis for theorizing about the basis for these patterns.

1. Inventories

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 have equal status in phonological systems. For example, many languages have the stop consonants [p t k], which are said to be unmarked, but relatively few have the uvular [q], which is said to be marked. Markedness is a comparative concept, so [q] is more marked that [k] but less marked than [ʕ]. Many languages have the voiced approximant [l], but few have the voiceless lateral fricative [ɬ] and even fewer have the voiced lateral fricative [ɮ]. Very many languages have the vowels [i e a o u]; not many have the vowels [ɯ ɜ ʊ ɪ].

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

The method of comparing inventories. Three methodological issues need to be born in mind when conducting such typological studies. First, determing what is more common versus less common requires a good-sized random sample of the languages of the world. However, information on phonological structure is not easily available for many of the languages of the world, and existing documentation tends to favor certain languages (for example the Indo-European languages) over other languages (those of New Guinea).

Second, it is often difficult to determine the true phonetic values of segments in a language which you do not know, so interpreting a symbol in a grammar may result in error. The consonants spelled <p t k> may in fact be ejective [p' t' k'], but <p t k> are used in the spelling system because *p, t, k* are "more basic" segments and the author of a grammar may notate ejectives with "more basic" symbols if no plain non-ejective voiceless stops exist in the language. This is the case in many Bantu languages of Southern Africa, such as Gitonga and Zulu, which contrast phonetically voiceless aspirated and ejective stops — there are no plain unaspirated voiceless stops. Therefore, the ejectives are simply written <p t k> because there is no need to distinguish [p] and [p']. This phonetic detail is noted in some grammars, but not in all, and if you do not have experience with the language and do not read a grammar that mentions that <p> is ejective, you might not notice that these languages have no plain voiceless stops.

Third, many typological claims are statistical rather than absolute — they are statements about what happens most often, and therefore encountering a language that does not work that way does not falsify the claim. It is very difficult to refute a claim of the form "X is more common than Y", except if a very detailed numerical study is undertaken.

Typical inventories. With these caveats, here are some general tendencies of phoneme inventories. In the realm of consonantal place of articulation, and using voiceless consonants to represent all obstruents at that place of articulation, the places represented by [p, t, k] are the most basic, occurring in almost all languages of the world. The next most common place would be alveopalatal; less common are uvulars, dentals and retroflex coronals; least common are pharyngeals. All languages have a series of simple consonants lacking secondary vocalic articulations.

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

The most common secondary articulation is rounding applied to velars, then palatalization; relatively uncommon is rounding of labial consonants; least common would be distinctive velarization or pharyngealisation of consonants. Among consonants with multiple closures, labiovelars like [kp] are the most common; clicks, though rare, seem to be more common that linguolabials.

In terms of manners of consonant articulation, stops are found in all languages. Most language have at least one fricative, and the most common fricative is *s*, followed by *f* and *š*, then *x*, then *θ* and other fricatives. The most common affricates are the alveopalatals, then the other coronal affricates; p^f and k^x are noticeably less frequent. In terms of laryngeal properties of consonants, all languages have voiceless consonants (in many, the voice onset time of stops is relatively long and the voiceless stops could be considered to be phonetically aspirated). Plain voiced consonants are also common, as is a contrast between voiceless unaspirated and voiceless aspirated stops. Ejectives, implosives and breathy-voiced consonants are much less frequent. Among fricatives, voicing distinctions are not unusual, but aspiration, breathy voicing and ejection are quite marked.

Nearly all languages have at least one nasal consonant, but languages with a rich system of place contrasts among obstruents may frequently have a smaller set of contrasts among nasals. Most languages also have at least one of [r] or [l], and typically have the glides [w y]. Modal voicing is the unmarked case for liquids, nasals and glides, with distinctive laryngealisation or devoicing ~ aspiration being uncommon. Among laryngeal glides, [h] is the most common, then [ʔ], followed by the relatively infrequent [ɦ].

The optimal vowel system would seem to be [i e a o u], and while the mid vowels [e o] are considered to be more marked that the high vowels [i u] for various reasons having to do with the operation of phonological rules (context-free rules raising mid vowels to high are much more common than context free rules lowering high vowels to mid), there are fewer languages with just the vowels [i u a] than with the full set [i u e o a]. The commonness of front rounded and back unrounded vowels is correlated with vowel height, so a number of languages have [ü] and not [ö], but very few have [ö] and not [ü]. Full exploitation of the possibilities for low back and round vowels ([æ œ ɑ ɒ] is quite rare, but it is not hard to find languages with [i ü ɨ u]. As noted earlier, oral vowels are more common than nasal vowels, and modal voiced vowels are more common than creaky voiced or breathy vowels.

2. Segmental processes

Recurrent paterns are also found in rules themselves. We begin our typological survey of processes with segmental processes and procede to prosodic ones. Put roughly, segmental phonology deals with how the features of one segment affect the features of another segment, and prosodic processes are those that pertain to the structure of syllables, stress and the rhythmic structure of words, and

phenomena which relate to the position of segments in a phonological string. This division of processes is at this point strictly heuristic, but research has shown that there are important representational difference between segmental i.e. featural representations, and syllabic or rythmic representations — further questions regarding representations are taken up in chapter 10.

2.1. Assimilations

The most common phonological process in language is **assimilation**, where two segments become more alike by having one segment take on values for one or more features from a neighboring segment.

Vowel harmony. An example of assimilation is vowel harmony, and the architypical example of vowel harmony is the front-back vowel harmony process of Turkish. In this language, vowels within a word are (generally) all front, or all back, and suffixes alternate according to the frontness of the preceding vowel. The genitive suffix accordingly varies between *in* and *ɨn*, as does the vowel of the plural suffix *lar ~ ler*.

(1)	*nom. sg.*	*gen. sg.*	*nom. pl.*	*gen. pl.*	
	ip	ip-in	ip-ler	ip-ler-in	“rope”
	čɨkɨš	čɨkɨš-ɨn	čɨkɨš-lar	čɨkɨš-lar-ɨn	“exit”
	kɨz	kɨz-ɨn	kɨz-lar	kɨz-lar-ɨn	“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) $V \rightarrow [\alpha\text{back}] / \underset{[\alpha\text{back}]}{V} \; C_0 \_\_$

A second kind of vowel harmony found in Turkish is rounding harmony. In Turkish, a rule assimilates any high vowel to the roundness of the preceding vowel. Consider the following data, involving stems which end in round vowels.

(3)	*nom. sg.*	*gen. sg.*	*nom. pl.*	*gen. pl.*	
	yüz	yüz-ün	yüz-ler	yüz-ler-in	“face”
	pul	pul-un	pul-lar	pul-lar-ɨn	“stamp”
	ok	ok-un	ok-lar	ok-lar-ɨn	“arrow”
	son	son-un	son-lar	son-lar-ɨn	“end”
	köy	köy-ün	köy-ler	köy-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 non-high vowel does not assimilate in roundness. Thus the data in (3) can be accounted for by the following rule.

(4) $\underset{[+high]}{V} \rightarrow [\alpha round] / \underset{[\alpha round]}{V} C_0 \_\_\_\_$

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 probably hypotheses are /a/ or /e/. For the genitive suffix, any of /i,ɨ,ü,u/ would be plausible, since from any of these vowels, the correct output will result by applying these rules.

It is sometimes assumed that, if all other factors are the same for selecting between competing hypotheses about the underlying form, a less marked (cross-linguistically frequent) segment should be selected over a more marked segment. By that reasoning, you might narrow the choice to /i,u/ since *ɨ,ü* are significantly more marked that /i,u/. The same reasoning might lead you to specifically conclude that alternating high vowels are /i/, on the assumption that *i* is less marked that *u*: however, that conclusion regarding markedness is not certain. The validity of invoking segmental markedness for chosing underlying forms is a theoretical assumption, and does not have clear empirical support. A further solution to the problem of picking between underlying forms is that [+high] suffix vowels are not specified for backness or roundness, and thus could be represented with the symbol /I/, which is not 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 non-high vowels undergo the assimilation, and only non-high vowels trigger the process.

(5)	*nominative*	*instrumental*	*accusative*	
	de:l	de:l-e:r	de:l-i:g	“coat”
	gal	gal-a:r	gal-i:g	“fire”
	dü:	dü:-ge:r	dü:-g	“younger brother”
	nöxör	nöxör-ö:r	nöxör-i:g	“comrade”
	doro:	doro:-go:r	doro:-g	“stirrup”

This rule can be forumlated as in (6).

(6) $V \rightarrow [\alpha\text{round}] / \begin{matrix}[-hi] \end{matrix} \quad V \quad C_0 \quad \begin{bmatrix}-hi \\ \alpha rd\end{bmatrix} \quad \_\_\_$

Typological research has revealed a considerable range of variation in the conditions that can be put on a rounding harmony rule. In Sakha, high vowels assimilate in roundness to round high and non-high vowels (cf. *aγa-lɨɨn* "father (assoc.)", *sep-tiin* "tool (assoc.)" vs. *oγo-luun* "child (assoc.)", *börö-lüün* "wolf (assoc.)", *tünnük-tüün* "window (assoc.)"), but non-round vowels only assimilate in roundness to a preceding non-high vowel (cf. *aγa-lar* "fathers", *sep-ter* "tools", *tünnük-ter* "windows", *kus-tar* "ducks" vs. *oγo-lor* "children", *börö-lör* "wolves"). As seen in Chapter 7, in Yokuts, vowels assimilate rounding from a preceding vowel of the same height (thus, high vowels assimilate to high vowels, low vowels assimilate to low vowels). Kirghiz vowels generally assimilate in roundness to any preceding vowel except that a non-high vowels does not assimilate to a back high round vowel (though it will assimilate rounding from a front high round vowel).

(7)

accusative	*dative*	*gloss*
taš-tɨ	taš-ka	stone
iš-ti	iš-ke	job
uč-tu	uč-ka	tip
konok-tu	konok-ko	guest
köz-tü	köz-gö	eye
üy-tü	üy-gö	house

This 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 members of the Altaic language family (e.g. Mongolian, Kirghiz, Turkish, Sakha). The existence of these kinds of rounding harmony means that phonological theory must provide the tools to describe them: what we do not know is whether other types of rounding harmony, not found in Altaic, also exist. Nor is it safe, given our limited database on variation within rounding harmony systems, to make very strong pronouncements about what constitutes 'common' versus 'rare' patterns of rounding harmony.

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

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

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

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

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

(10) $$V \rightarrow [+hi] / \_\_\_ C_0 \; V$$
$$[+tense] \qquad\qquad [+hi]$$

Another variety of vowel height harmony is complete height harmony, an example of which is found in Kimatuumbi. This language distinguishes four phonological vowel heights, examplified by the vowels *a, ɛ, ɪ* and *i*. The vowels of the passive suffix *-ilw-* and the causative suffix *-iy-* assimilate completely to the height of the preceding non-low vowel *ɛ, ɪ* and *i*.

(11)	ásim-a	"borrow"	ásim-ilw-a	"be borrowed"
	ín-a	"dance"	in-ilw-a	"be danced"
	kún-a	"grate coconut"	kún-ilw-a	"be grated"
	úʊg-a	"bathe"	úʊg-ɪlw-a	"be bathed"
	twíɪk-a	"lift a load"	twíɪk-ɪlw-a	"be lifted"
	bɔ́ɔl-a	"tear bark off a tree"	bɔ́ɔl-ɛlw-a	"be de-barked"
	kɛ́ɛŋgɛɛmb-a	"uproot tubers"	kɛ́ɛŋgɛɛmb-ɛlw-a	"be uprooted"

čáag-a	"grind"	čáag-iy-a	"make grind"
číinj-a	"slaughter"	číinj-iy-a	"make slaughter"
úʊg-a	"bathe"	úʊg-ɪy-a	"make bathe"
bɔ́ɔl-a	"de-bark"	bɔ́ɔl-ɛy-a	"make de-bark"
čɛ́ɛŋg-a	"build"	čɛ́ɛŋg-ɛy-a	"make build"

This process involves the complete assimilation of suffix vowels to the values of [hi] and [tense] (or [ATR]) from the preceding non-low vowel. Since the low vowel *a* does not trigger assimilation, the context after *a* reveals the underlying nature of harmonizing vowels, which we can see are high and tense. The following rule will account for the harmonic alternations in (11).

(12) $$\begin{bmatrix} \text{V} \\ \text{-low} \end{bmatrix} \rightarrow \begin{bmatrix} \alpha\text{hi} \\ \beta\text{tense} \end{bmatrix} / \begin{bmatrix} \text{-low} \\ \alpha\text{hi} \\ \beta\text{tense} \end{bmatrix} \text{C}_0 \_\_$$

Akan exemplifies a type of vowel harmony which is common especially among the languages of Africa, which is assimilation of the feature ATR. In Akan, vowels within the word all agree in their value for [ATR]. In (13a) the prefix vowels are [+ATR] before the [+ATR] vowel of "eat" and [-ATR] before the [-ATR] vowel of "be called"; (13b) shows this same harmony affecteing other tense-aspect prefixes.

(13) a.

	"eat"	"be called"
1s	mi-di	mɪ-dɪ
2s	wu-di	wʊ-dɪ
3s	o-di	ɔ-dɪ
1p	ye-di	yɛ-dɪ
2p	mu-di	mʊ-dɪ
3p	wo-di	wɔ-dɪ

b.

o-be-di	"he will eat"	ɔ-bɛ-dɪ	"he'll be called"
o-di-i	"he ate"	ɔ-dɪ-ɪ	"he was called"
o-ko-di	"he goes and eats"	ɔ-kɔ-dɪ	"he goes and is called"

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

(14)			
	mlɛɛbo	mlɛɛbo-i	"liver"
	nãne	nãne-i	"leg"
	čĩĩsi	čĩĩsi-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) $$\varepsilon \rightarrow \begin{bmatrix} \alpha\text{round} \\ \beta\text{tense} \\ \gamma\text{back} \end{bmatrix} / \_\_ \; C_0 \begin{bmatrix} \text{V} \\ \alpha\text{round} \\ \beta\text{tense} \\ \gamma\text{back} \end{bmatrix}$$

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

(17)	*stem*	*1s pres*	*1s past*	*imperative*	
	/tum/	tum-atun	tum-tan	tum	'sneeze'
	/agul/	agul-atun	agul-tan	agul	'dig'
	/dakap/	dakap-atun	dakap-tan	dakap	'push'

/katk/	katk-atun	katak-tan	katak	‘strike’
/melg/	melg-atun	meleg-tan	meleg	‘shake’
/kink/	kink-atun	kinik-tan	kinik	‘break’

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

(18)

sna-batgal	“gets someone up from bed”
sne-l’e:ml’ema	“makes someone dizzy”
sno-bo:stgi	“causes something to turn black”
sni-nklilk’a	“makes dusty”

Complete harmony is unlikely to ever be completely general — all of these examples are restricted in application to specific contexts, such as epenthetic vowels as in Kolami, or vowels of specific affixal morphemes as in Klamath. Another 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 illlustrated in Nenets by the alternation in the locative forms *to-hona* “lake”, *pi-hina* “street”, *pʸa-hana* “tree”, *pe-hena* “stone”, *tu-huna* “fire”. The consequences of a completely unrestricted vowel harmony would be rather drastic — any word could only have one kind of vowel in it, were such a rule to be totally general.

Consonant assimilations. One of the most common processes affecting consonants is the assimilation of a nasal to the place of articulation of a following consonant. An example of this process comes from Kimatuumbi, seen in (19), where the plural prefix /ñ/ takes on the place of assimilation of the following consonant.

(19)

Singular	*Plural*	
lwɪ́mo	ñímo	“land being weeded”
lwaámbo	ñaámbo	“bead”
lweémbe	ñeémbe	“shaving knife”
lugolóká	ŋgolóká	“straight”
lubáu	mbáu	“rib”
luǰiíŋgyá	ñǰiíŋgyá	“entered”
lulaála	ndaála	“pepper”
lupaláaí	mbaláaí	“bald head”
lutéelá	ndeelá	“piece of wood”
lučwiíčwi	ñǰwiíčwi	“tomato”
lukíligo	ŋgilígo	“place for initiates”
lukíli	ŋgíli	“palm”

Place assimilation of nasals in Kimatuumbi affects all nasals, so the data in (20a) illustrate assimilation of preconsonantal /n/ resulting from an optional vowel deletion rule, and (20b) illustrates assimilation of /m/.

(20) a.

ni-bálaaŋgite	m-bálaaŋgite	"I counted"
ni-ǰíiŋgiile	ñ-ǰíiŋgiile	"I entered"
ni-góoñ̃jite	ŋ-góoñ̃jite	"I slept"

b.

mu-páalite	m-páalite	"you (pl.) wanted"
mu-téliike	n-téliike	"you (pl.) cooked"
mu-čáawiile	ñ-čáawiile	"you (pl.) ground"
mu-káatite	ŋ-káatite	"you (pl.) cut"

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

(21)

teŋ-əɬʔ-ən	"good"
tam-waɣərɣ-ən	"good life"
tam-pera-k	"to look good"
tan-čotčot	"good pillow"
tan-ɬəmŋəɬ	"good story"
tan-rʔarqə	"good breastband"
nə-mkə-kin	"often"
ɣa-n-pera-w-ɬen	"decorated"

Not all preconsonantal nasals condition this voicing process in Kimatuumbi; only nasals which are non-syllabic in the intermediate representation do. Hence [mp] sequences, such as found in (20), are possible, since the process that deletes the vowel *u* results in a syllabic nasal in the intermediate representation

A common assimilation affecting consonants after nasals is postvocalic voicing, illustrated with by Kimatuumbi in (22). The data in (22a) illustrates voicing of an underlyingly voiceless consonant at the beginning of a stem after the prefix *ñ*. The data in (22b) show voicing of a consonant in a verb after the reduced form of the subject prefix *ni*. Here, the vowel /i/ in the prefix optionally deletes, and when it does, it causes a change in the voicing of an initial stop.

(22) a.

Singular	*Plural*	
lu-paláaí	m-baláaí	"bald head"
lu-čwiíčwi	ñ-ǰwiíčwi	"tomato plant"
lu-téelá	n-deelá	"piece of wood"
lu-kíligo	ŋ-gilígo	"initiate's place"
lu-temá.á	n-demá.á	"chopped"
lu-čapíičá	ñ-ǰapíičá	"clean"

b.	*1s. past*	*optional pronunciation*	
	ni-páalite	m-báalite	“I wanted (recent)”
	ni-téliike	n-déliike	“I cooked (recent)”
	ni-čónite	ñ-ǰónite	“I sewed (recent)”
	ni-kúbiile	ŋ-gúbiile	“I hit on legs (recent)”

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 *-n̈inta*.

(23)		*Infinitive*	*Past*	
	a.	an-a	an-n̈inta	“hug”
		t’aẗim-ə	t’aẗim-n̈inta	“trim”
		nəm-ə	nəm-n̈inta	“overflow”
		č^{h}am-a	č^{h}am-n̈inta	“endure”
	b.	ip-ə	im-n̈inta	“wear”
		tat-ə	tan-n̈inta	“close”
		put^{h}-ə	pun-n̈inta	“adhere”
		čoč^{h}-a	čon-n̈inta	“follow”
		mək-ə	məŋ-n̈inta	“eat”
		tak’-a	taŋ-n̈inta	“polish”
		ik-ə	iŋ-n̈inta	“ripen”

Kimatuumbi presents the mirror-image process, of post-nasal nasalization (this process is only triggered by nasals which are moraic in the intermediate representation). On the left in (24a), the underlying consonant is revealed when a vowel-final prefix noun class prefix stands before the stem, and on the right a nasal prefix stands before the stem, causing the initial consonant to become nasalized. In (24b), nasalization applies to the example in the second column, which undergoes an optional rule deleting the vowel *u* from the prefix /mu/.

(24)	a.	a-baánda	“slaves”	m-maánda	“slave”
		a-láalo	“fools”	n-náalo	“fool”
		a-gúndumúyi	“scarers”	ŋ-ŋúndumúyi	“scarer”
		mi-butúka	“cars”	m-mutúka	“car”
		mi-dálaánzi	“bitter oranges”	n-nálaánzi	“bitter orange”
		mi-lipú	“trees (sp.)”	n-nipú	“tree (sp.)”
		mi-gúunda	“fields”	ŋ-ŋúunda	“field”

b.	mu-buundíke	m-muundíke	"you should store"
	mu-laabúke	n-naabúke	"you should breakfast"
	mu-jiiŋgí	ñ-ñiiŋgí	"you should enter"

Many languages have a process of voicing assimilation, especially in clusters of obstruents which must agree in voicing. Most often, obstruents assimilate regressively to the last obstruent in the cluster. For example, in Sanskrit a stem final consonant reveals its underlying voicing when the following affix begins with a sonorant, but assimilates in voicing to a following obstruent.

(25)			
	kr̥ṇṭ-mas	b^hind-mas	1pl indicative active
	kr̥ṇṭ-e	b^hind-e	1sg indicative middle
	kr̥ṇṭ-$ṭ^h$a	b^hint-t^ha	2pl indicative active
	kr̥ṇṭ-ṭe	b^hint-te	3sg indicative middle
	kr̥ṇḍ-$ḍ^h$ve	b^hind-d^hve	2pl indicative middle
	"weave"	"bind"	

Other languages with regressive voicing assimilation are Hungarian and Russian.

Progressive voicing harmony is also possible, though less common than regressive voicing. One example of progressive assimilation is found in Norwegian. The (regular) past tense suffix is *-te*, and shows up as such when attached to a stem ending in a sonorant or voiceless consonant, but after a voiced obstruent, the suffix appears as *-de*.

(26)						
	smil-e	smil-te	"smile"	svøm-e	svøm-te	"swim"
	hør-e	hør-te	"heard"	lon-e	lon-te	"borrow"
	les-e	les-te	"read"	spis-e	spis-te	"eat"
	reis-e	reis-te	"travel"	çøp-e	çøp-te	"buy"
	tenk-e	tenk-te	"think"	behøv-e	behøv-de	"belong"
	lev-e	lev-de	"lived"	prøv-e	prøv-de	"try"
	bygg-e	byg-de	"build"	hugg-e	hugg-de	"chop"
	gnag-e	gnag-de	"gnaw"	krev-e	krev-de	"request"
	sag-e	sag-de	"saw"	plag-e	plag-de	"afflict"

Another example of progressive voicing harmony is found in Evenki, where an underlyingly voiced suffix-initial consonant becomes devoiced after a voiceless obstruent: this is illustated below with the accusative case suffix /ba/.

(27)				
	asi:-ba	'woman'	ɲami:-ba	'female deer'
	palatka-ba	'tent'	tolgolki:l-ba	'sleds'
	ber-be	'onion'	huna:t-pa	'girl'
	det-pe	'tundra'	mit-pe	'1 pl inclusive'

Complete assimilation of a consonant to a following consonant is found in Arabic. In the data of (28) from the Syrian dialect, the consonant /l/ of the definite article assimilates completely to a following coronal consonant. Examples in (a) show non-assimilation when the following consonant is non-coronal, and those in (b) provide stems that begin with coronal consonants.

(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"	ħa:ra	lħa:ra	"quarter"
	waħš	lwaħš	"beast"	yaʔs	lyaʔs	"despair"
	kalb	lkalb	"dog"	xadd	lxadd	"cheek"
	fayy	lfayy	"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"
	šo:raba	ššo:raba	"soup"	žamil	žžamil	"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"	vkusʸ-en	"tasty"
	um	"intellect"	umʸ-en	"clever"
	golot /d/	"hunder"	golodʸ-en	"hunger"
	stol	"table"	stolʸ-e	"table (loc.)"
	guba	"lip"	gubʸ-e	"lip (loc.)"
	mesto	"place"	mestʸ-e	"place (loc.)"
	glub-ok	"deep"	glubʸ-ina	"depth"
	ton-ok	"thin"	tonʸ-ina	"thinness"
	vor	"thief"	vorʸ-iska	"thief (pejorative)"
	dom	"house"	domʸ-iska	"house (pejorative)"
	gorot /d/	"town"	gorodʸ-iska	"town (pejorative)"

A second kind of palatalization is found in many languages, where typically velar but in some languages also alveolar consonants become alveopalatals:

to avoid confusion with the preceding type of palatalization as secondary articulation, this latter process is often referred to as **coronalization**. This process is found in Russian: it is triggered by some derivational suffixes with front vowels, but not all suffixes.

The alveopalatal fricatives *š, ž* are not phonetically palatalizable in Russian, whereas the alveopalatal affricate is always palatalized

(30)				
	druk /g/	"friend"	druž-it^{y}	"to be friends with"
	muka	"torment"	muč^{y}-it^{y}	"to torment"
	grex	"sin"	greš-it^{y}	"to sin"
	strok /g/	"strict"	strož-e	"stricter"
	dik	"wild"	dič^{y}-e	"wilder"
	sux	"dry"	suš-e	"stricter"
	krut	"steep"	kruč^{y}-e	"steeper"
	gad-ok	"foul"	gaž-e	"fouler"
	vɨs-ok	"tall"	vɨš-e	"taller"
	niz-ok	"low"	niž-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 [č] before [u].

(31)	*negative*	*provisional*	*infinitive*	*volitional*	
	mat-anai	mat-eba	mat^{s}-u	mač-itai	"wait"
	tat-anai	tat-eba	tat^{s}-u	tač-itai	"stand"
	kat-anai	kat-eba	kat^{s}-u	kač-itai	"win"

Outside of the domain of assimilations in place of articulation, the most common segmental interaction between consonants and vowels (or, sometimes, other sonorants) is **lenition** or **weakening**. Typical examples of lenition either involve the voicing of voiceless stops, or the voicing and spirantization of stops: the conditioning context is a preceding vowel, sometimes a preceding and following vowel. An example of the spirantization type of lenition is found in Spanish, where the voiced stops /b,d,g/ become voiced spirants [β,ð,γ] after vowels.

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

This can be seen as assimilation of the value [continuant] from a preceding vowel.

An example of combined voicing and spirantization is found in Tibetan, where voiceless non-coronal stops become voiced spirants between vowels.

(33)

past affirmative	*past negative*	*gloss*
čaa-βəree	ma-čaa-βəree	‘go’
paa-βəree	ma-βaa-βəree	‘light’
pii-βəree	mə-βii-βəree	‘renounce’
kuu-βəree	mə-ɣuu-βəree	‘wait’
kə-βəree	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 [y,w] after a vowel.

(34)

yaarato	“black bee”	no-yaaratoti	“my black bee”
kanari	“wild turkey”	no-yanariti	“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 Kimatuumbi, sonorants become voiced stops after a nasal. The data in (35) illustrate this phenomena with the alternation in stem-initial consonant found between the singular and plural.

(35)

lu-laála	“pepper plant”	n-daála	“pepper plants”
lu-yímá	“pole”	ñ-ǰíma	“poles”
yúkuta	“to be full”	ñ-jukúta	“full”
wá	“to die”	ŋ-gwaá.á	“dead”
líndɪla	“to guard”	n-dɪndílá	“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 *d*, so that [cabbi] derives from /caw-dí/ via the intermediate stage *cawwi*).

(36)

pl	dim sg	
čabbi	čawel	“stick”
lebbi	lewel	“month”
pobbi	powel	“hyena”
ɲɛbbɛ	ɲewel	“bean”
leppi	lefel	“ribbon”
koppi	kofel	“ear”
čoppi	čofel	“chick”

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

(37)	*singular*	*plural*	
	ggi	ma-gi	"egg"
	ddaala	ma-daala	"ladder"
	ǰǰuba	ma-yuba	"dove"
	gg^{w}aanga	ma-waanga	"nation"
	ddaanga	ma-laanga	"lily"

In this language, only sonorants harden to stops.

(38)	*singular*	*plural*	
	ffumu	ma-fumu	"spear"
	ffuumbe	ma-fuumbe	"civet"
	ssaanja	ma-saanja	"dry plaintain leaf"
	zzike	ma-zike	"chimpanzee"
	zziga	ma-ziga	"tear"
	vviivi	ma-viivi	"knee"

2.2. Dissimilation

Less common in the languages of the world are processes of dissimilation, whereby one of two similar consonants changes to become less like the other. An example of such a process is lateral dissimilation found in Sundanese. In this language, the plural is formed by infixing *-ar-* after the initial consonant, as seen in (39a). When another *r* follows within the stem, the *r* of the infix dissimilates to *l*.

(39)		*Singular*	*Plural*	
	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"
		combrek	c-al-ombrek	"cold"
		bocor	b-al-ocor	"leaking"
		bɨŋhar	b-al-ɨŋhar	"rich"
		hormat	h-al-ormat	"respect"

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

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

Dissimilation of aspiration is attested in 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"
	kʰoy-dok	"trim out"	kʰoy-gət	"trim upwards"
	tʰin-dok	"pierce out"	tʰin-gət	"pierce upwards"

Many Bantu languages such as Kikuria have a voicing dissimilation process whereby *k* becomes *g* when the following syllable has a voiceless consonant (excluding *h*). This results in alternations in the form of the infinitive prefix which is underylyingly /oko/, as well as the 2sg object prefix /ko/ and the (diminutive) object prefix /ka/. The data in (42a) motivate the underlying prefix /oko/ and (42b) shows application of dissimilation to the prefix. (42c) shows the object prefixes /ko/ and /ka/ which also dissimilate, and (42d) shows the contrasting prefixes /go/ and /ga/ which have underlyingly voiced consonants, and do not assimilate.

(42)	a.	oko-réma	"to cultivate"	uku-ñáhaaréka	"to be hurt"
		uku-míñooŋgóra	"to crush"	uku-gííŋgírá	"to shave"
		oko-gɔ́ɔ́gá	"to slaughter"	uku-búna	"to break"
		oko-bɔ́cha	"to vomit"	oko-hóóra	"to thresh"
	b.	ogo-tááŋgá	"to begin"	ugu-túúhá	"to be blunt"
		ugu-súraaŋgá	"to sing praise"	ogo-sɛ́ɛ́nsá	"to winnow"
		ugu-kyá	"to dawn"	ogo-kɛ́ña	"to run"
	c.	ogo-kó-bárǎ	"to count you sg"		
		uku-gú-súraáŋga	"to praise you sg"		
		ogo-ká-bárǎ	"to count it"		
		oko-gá-súraáŋga	"to praise it"		

d.	oko-gó-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-taraɣ-more	"we built a dwelling"
	mətɬəŋ-ən	"five"	mətɬəɣ-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"
	ətɬəɣ-ən	"father"	ətɬək-ɣəyiwq-ew	"paternal marking"
	rəɣrəɣ	"wool"	rəɣrək-ɣəpə	"from wool"
	yeɣteɬ-ək	"to live"	ɣe-yeɣtet-ɬin	"he lived"
	ɬəmŋəɬteɬ-ək	"tell stories"	ɣa-ɬəmŋəɬtet-ɬen	"told stories"
	ŋew-ʔen	"woman"	ŋak-waŋe-ɣərɣ-ən	"woman's sewing"
	iɬɣətew-ək	"to wash"	iɬɣətek-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)	kətəyɣat-ək	"blow"	ɣa-n-pera-w-ɬen	"decorated"
	ʔiw-pipiq-əɬɣ-ən	"wolf mouse"		

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

(46)	wʔeɣ-ək	"grass"	wʔeɣ-ti	"grasses"
	ŋin-qey	"boy"	ŋen-qaɣ-čəŋ-ən	"big boy"
	čaɣ	"tea"	čaɣ-naɬk-ək	"to make tea"
	qeɣ-we	"correct"	qeɣ-ɬənanɣet	"truth"
	qeyəqeɣ	"nestling"	qaɣ-yaʔyaq	"young seagull"

Dissimilation between vowels is also found in languages. One case comes from Woleiaian, where the low back vowel /a/ becomes [e] before the low back vowels /a/ and /ɔ/. This process affects the causative prefix /ga/, seen below.

(47)	ga-repa	"approach it"	ga-beši	"heat it"
	ga-siwe	"make it stand"	ga-sere	"make it hit"
	ge-bbaro	"bend it"	ge-maki	"give birth to him"

ge-mɔwe	“erase it”	ge-tɔtɔwe	“support it”
ge-waʂir	“hurt it”	ge-tɔla	“make it bloom”

In Wintu, the vowels /e, o/ become [i,u] before /a/ by a similar kind of dissimilation.

(48)				
	/lel-a/	→	lila	“to transform”
	/lel-u/	→	lelu	“transform!”
	/lel-it/	→	lelit	“transformed”
	/dek-a/	→	dika	“to climb”
	/dek/	→	dek	“climb!”
	/dek-na:/	→	dekna:	“to step”
	/doy-a:/	→	duya:	“to give”
	/doy-u/	→	doyu	“give!”
	/doy-i/	→	doyi	“gift”

Examples of low vowel dissimilating to non-low vowels before low vowels are also found in Kera and Southern Russian. Interestingly, most examples of dissimilation between vowels are precisely of this nature: we do not seem to find cases of high vowels dissimilating to non-high near other high vowels.

2.3. Other Segmental Processes

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

(49)	*Infinitive*	*Conjunctive*	
	ip-ə	ip-k’o	“wear”
	kap^{h}-a	kap-k’o	“pay back”
	tat-ə	tat-k’o	“close”
	put^{h}-ə	put-k’o	“adhere”
	čoč^{h}-a	čot-k’o	“follow”
	mək-ə	mək-k’o	“eat”
	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, š*, i.e. the voiceless coronal non-affricates. The data in (50) show that noun stems can end in an array of consonants, as revealed by the essive form of the noun which

takes the suffix -(*i*)*n*, but in the nominative, which has no suffix, all places of articulation are neutralized to coronal.

(50)

nominative sg.	*essive*	
oahpis	oahpis-in	"acquaintance"
čoarvuš	čoarvuš-in	"antlers & skullcap"
gahpir	gahpir-in	"cap"
heevemeahhtun	heevemeahhtun-in	"inappropriate"
varit	varih-in	"2 year old reindeer buck"
čuoivvat	čuoivvag-in	"yellow-brown reindeer"
ahhkut	ahhkub-in	"grandchild of woman"
lottaaš	lottaǰ-in	"small bird"
suohkat	suohkað-in	"thick"
jaaʔmin	jaaʔmim-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.

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 Kimatuumbi, high vowels become glides before other vowels, as shown by the data in (51). The examples on the left show that the noun prefixes have underlying vowels, and those on the right illustrate application of glide formation.

(51)

mi-kaáte	"loaves"	my-oótó	"fires"
li-kuŋuúnda	"filtered beer"	ly-oowá	"beehive"
ki-kálaaŋgo	"frying pan"	ky-uúlá	"frog"
i-kálaaŋgo	"frying pans"	y-uúlá	"frogs"
lu-toóndwa	"star"	lw-aaté	"banana hand"

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", *ipʊkú* "rats".

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

Vowel sequences can also be eliminated by coalescing the two vowels into a single vowel, often one which preserves characteristics of the individual vowel. This happens in Kimatuumbi as well, where the combinations /au/ and /ai/ become [oo] and [ee]. This rule is optional in Kimatuumbi, so the uncoalesced vowel sequence can also be pronounced (thus motivating the underlying representation).

(52)

a-i-téliike	ee-téliike	"he cooked them"
pa-ú-kaátité	poó-kaátité	"when you cut"
pa-bá-i-káatité	pa-bée-káatité	"when they cut them"
a-u-káatite	oo-káatite	"he cut it"
ka-u-tʊʊmbúka	koo-tʊʊmbúka	"when it was falling"
pa-i-taábu	pee-taábu	"where the books are"
pa-u-títili	poo-títili	"where the chicken louse is"
ka-u-méyá	kooméyá	"little white ant"
na-u-čaápu	noo-čaápu	"with dirt"

The change of /au/ and /ai/ to [oo] and [ee] can be seen as creating a compromise vowel, one which preserves the height of the initial vowel /a/, and the backness and roundness of the second vowel.

Sometimes, vowel sequences are avoided simply by deleting one of the vowels, with no compensatory lengthening. Thus at the phrasal level in Shimakonde, word-final /a/ deletes before an initial vowel, cf. *lipeeta engaanga* → *lipeet engaanga* 'the knapsack, cut it!', *likuka engaanga* → *likuk engaanga* 'the trunk, cut it!', *nneemba idanaao* → *nneemb idanaao* 'the boy, bring him!'.

Consonant 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”
	yara	yarna	“drink”
	woya	woyna	“cry”
	ǰu:la	ǰu:lna	“be Muslim”
	wurto	wurtina	“come out”
	wuǰǰa	wuǰǰina	“steal”
	yotto	yottina	“arrive”

Another form of vowel epenthesis is that it to eliminates certain kinds of consonants in a particular position. The only consonants at the end of the word in Kotoko are sonorants, so while the past tense of the verbs in (54a) is formed with just the stem, the verbs in (54b) require final epenthetic schwa.

(54)	*Infinitive*	*Past*		*Infinitive*	*Past*	
a.	hàm-à	hám	“yawn”	ɗàn-à	ɗàn	“tie”
	skwàl-à	skwál	“want”	vèr-à	vèr	“fly”
	ləhày-à	ləhày	“fear”	làw-à	làw	“fight”
b.	gəɓ-à	gəɓə	“answer”	kàɗ-à	káɗə	“cross”
	làb-à	làbə	“tell”	ǰàg-à	ǰàgə	“cook”
	gìč-à	gìčə	“sweep”	ʔək-à	ʔəkə	“take by force”
	sàp-à	sapə	“chase”	vìt-à	vìtə	“blow on a fire”
	vənàh-à	vənàhə	“vomit”	həs-à	həsə	“spill”
	ɗəv-à	ɗəvə	“put”	bàɣ-à	bàɣə	“split wood”

Another factor motivating epenthesis is a word-size, viz. the need to avoid monosyllabic words. One example is seen in the following data from Mohawk, where the 1 sg. prefix is preceded by the vowel *i* just in case is it attached to a monosyllabic stem.

(55)		
	k-atirút-haʔ	“I pull it”
	k-ataʔkeráhkwaʔ	“I float”
	k-kétskw-as	“I raise it”
	k-hní:nus	“I buy”
	k-tat-s → íktats	“I offer it”
	k-yʌ-s → íkyʌs	“I put it”
	k-ket-s → íkkets	“I scrape it”

The adaptation of loanwords into Saami from Scandinavian languages (Norwegian or Swedish) illustrates a variant on the Mohawk-type minimal-word motivation for epenthesis. In this case, a vowel is inserted to prevent a monosyllabic stress foot — though interestingly this requirement is determined on the basis

of the Norwegian source, whereas in the Saami word stress is (predictably) on the first syllable. Except for a small set of "special" words (pronouns, grammatical words), words in Saami must be at least two syllables long. Thus the appearance of a final epenthetic vowel in the following loanwords is not surprising.

(56)	*Saami*	*Norwegian*	
	daaigi	deig	'dough'
	niibi	kniv	'knife'
	vouʔna	vogn	'wagon'
	muura	mur	'wall'

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

(57)	*Saami*	*Norwegian*	
	diisdat	tírsdag	'Tuesday'
	kaavrret	kávring	'rusk'
	akaðemihkar	akadémiker	'academic'
	miniistar	miníster	'minister'
	teahter	teáter	'theater'
	tempel	témpel	'temple'
	orgel	órgel	'organ'
	profes'sor	proféssor	'professor'
	plasttar	pláster	'plaster'
	kaahkal	kákkel	'glazed tile'

The above examples are ambiguous in analysis, since the source word is both polysyllabic, and has a non-final stress. The examples in (58), on the other hand, show epenthesis when the stress-foot in the source word is monosyllabic, even though the overall word is polysyllabic.

(58)	hoteella	hotéll	'hotel'
	maratona	maratón	'marathon'
	universiteehta	universitét	'university'
	tabeal'la	tabéll	'(time-)table'
	privaahta	privát	'private'
	kameela	kamél	'camel'
	polaara	polár	'polar'

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 and if a word has no underlying initial conso-

nant a glottal stop is inserted, thus /al-walad/ → [ʔalwalad] "the boy". In the Hare & Bearlake dialects of Slave, words cannot begin with a vowel, so when a vowel-initial root stands at the beginning of a word (including in a compound), the consonant *h* is inserted.

(59)		
	s-õdee	"my older brother"
	dene-[h]õdee	"Brother (in church)"
	n-anay	"your sg. sister-in-law (man speaking)"
	[h]anay	"sister-in-law"
	b-ek'éhdí	"I take care of him/her"
	bebí [h]ek'éhdí	"I take care of the baby"
	ku-edehfe → kúdehfe	"I chased them"
	sah [h]edéhfe	"s/he chased the bear"

In Axininca Campa *t* is inserted between vowels — this language does not have a glottal stop phoneme. Thus, /i-N-koma-i/ → [inkomati] "he will paddle".

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 simplifiation is found in Korean.

(60)	imperative	conjunctive	indicative	gloss
	palp-a	pal-k'o	pal-t'a	tread on
	ulph-ə	ul-k'o	ul-t'a	chant
	ilk-ə	il-k'o	il-t'a	read
	halth-a	hal-k'o	hal-t'a	taste
	talm-a	tam-k'o	tam-t'a	resemble
	anc-a	an-k'o	an-t'a	sit down

Another cause of cluster simplification is the avoidance of certain specific types of consonant clusters. Shona avoids clusters of the form Cy although Cw is perfectly acceptible. The deletion of *y* after a consonant affects the form of possessive pronouns in various noun classes. Demonstratives and possessive pronouns are formed with an agreement prefix reflecting the class of the noun, plus a stem, *-no* for "this" and *-angu* for "my". Before the stem *-angu*, a high vowel becomes a glide. Just in case this would result in a Cy sequence, the glide is deleted.

(61)	'this'	'my'	class
	u-no	w-angu	3
	mu-no	mw-angu	18
	ku-no	kw-angu	17
	ru-no	rw-angu	11

i-no	y-angu	9
ri-no	r-angu	6
či-no	č-angu	7
ẓ^{w}i-no	ẓ^{w}-angu	8
dᶻi-no	dᶻ-angu	10

Since /i-angu/ becomes *yangu*, it is evident that the vowel *i* does become a glide before a vowel rather than uniformly deleting.

Since Makonde is also a tone language and the accute accent is used to mark H tone, not stress, stress will be indicated with the mark 'ˈ' before the stressed syllable.

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-áán-a	"to cultivate each other"
	kú-lím-áˈn-ííl-a	"to cultivate for each other"
	kú-lím-án-íl-á-lím-áˈn-ííl-a	"to cultivate for each other continuously"

A related process is the reduction of unstressed vowels, as found in English. From alternations like *bərˊmətr̩ ~ bɛ̀rəmɛ́trɪk*, *mˊnəpòwl ~ mənˊpəliy*, we know that unstressed vowels in English are reduced to schwa. Russian also reduces unstressed nonhigh vowels so that /a,o/ become [ə], or [a] in the syllable immediately before the stress.

(63)	/gorod-ók/ → [gəradók]	"cities"	/górod/ → [górəd]	"city"
	/pó-da-l/ → [pódəl]	"he gave"	/po-dá-tʸ/ → [padátʸ]	"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	1s	
ḥámal	ḥámalat	ḥamált	"carry"
kátab	kátabat	katábt	"write"
dáras	dárasat	darást	"study"
šírib	šírbat	šríbt	"drink"
nízil	nízlat	nzílt	"descend"
fíhim	fíhmat	fhímt	"understand"

Syllable weight limits. Many languages disallow long vowels in syllables closed by consonants, and the following examples from Yawelmani show that this lan-

guage enforces such a prohibition against VVC syllables by shortening the underlying long vowel.

(65)

	nonfuture	*imperative*	*dubitative*	*passive aorist*	
/CVC/	xathin	xatk'a	xatal	xatit	'eat'
	doshin	dosk'o	do:sol	do:sit	'report'
/CVVC/	ṣaphin	ṣapk'a	ṣa:pal	ṣa:pit	'burn'
	wonhin	wonk'o	wo:nol	wo:nit	'hide'

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)

tíralk	'saliva'	mérepèt	'beard'
yángarmàta	'the Pleaiades'	lángkaràtetì	'prawn'
wélepènemànta		'duck (sp.)'	

A variant of this pattern occurs in Araucanian, where the main stress appears on the second syllable, and secondary stresses appear on every even numbered syllable following.

(67)

wulé	'tomorrow'
t̪ipánto	'year'
elúmuyù	'give us'
elúaènew	'he will give me'
kimúbalùwulày	'he pretended not to know'

The mirror image of the Maranugku pattern is found in Weri, where the last syllable has the main stress and every other syllable preceding has secondary stress.

(68)

ŋintíp	'bee'
kùlipú	'hair of arm'
ulùamít	'mist'
àkunètepál	'times'

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

(69)	yiwàranáe	'he finished it'
	yàpurùkitàneháse	'verily to climb'
	enàhoròahàkutái	'the one who caused him to eat'

Another property exhibited by many stress systems is quantity-sensitivity, where stress is assigned based on the weight of a syllable. Palestinian Arabic has such a stress system, where stress is assigned to the final syllable if that syllable is heavy, to the penult is the penult is heavy and the final syllable us light, and to the antepenult otherwise. The typical definition of a heavy syllable is one with either a long vowel ofr a final consonant; however, it should be noted that in Arabic, final syllables have a special definition for 'heavy', which is that a single consonant does not make the syllable heavy, but two consonants do.

(70)	radyóo	"radio"	qaréet	"I read"
	katábt	"I wrote"	qára	"he read"
	qárat	"she read"	katábna	"we wrote"
	qaréethum	"I read them"	kátabu	"they wrote"
	kátabat	"she wrote"	ma katabátš	"she didn't write"

4. Why do things happen?

Two of the central questions which phonological theory has sought answers to are "why does rule X exist?" and "can rule Y exist?". Very many languages have a process changing velars into alveopalatals (k → č) before front vowels, and a rule voicing voiceless stops after nasals (mp → mb) is also quite common. It is natural to wonder why such rules would occur in many languages, and a number of theoretical explanations have been offered to explain this. It is also important to also ask about imaginable rules: we want to know, for example, if any language has a rule turning a labial into an alveopalatal before a front vowel, one devoicing a voiced stop after a nasal, or one turning {s,m} into {l,k} before {w,š}. Only by contrasting attested with imagineable 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} → {l,k}/ __{w,š} is "unnatural", and any theory which predicts such a rule would not be a useful theory. We have seen in Chapter 6 that it is impossible to formulate such a process given the theory of distinctive features, since the classes of segments 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 sense technical 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).

(71) a.

mč → ñč	ŋč → ñč
ñp → mp	np → mp
ñk → ŋk	nk → ŋk
ñt → nt	nč → ñč

b.

mč → nč (not ñč)	ŋč → ñč
ñp → ŋp	np → mp
ñk → ŋk	nk → mk
ñt → ñt	nč → nč

The pattern of alternation in (a) is quite common, and was exemplified earlier in this chapter as nasal place assimilation. The second pattern of alternation in (b), on the other hand, is not attested in any language. Given the nonexistence of the pattern (b), we may ask "why is this pattern not attested".

The easy answer to this question is that pattern (b) is not phonetically natural. This begs the question of how we know what is a phonetically natural versus an unnatural pattern, and unfortunately the connection between "actually attested phonological rule" and "phonetically natural" are so closely intertwined that 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 10 — but in one theory, the so-called linear theory practiced in the 1960's and 1970's, 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 1970's, has a different answer: formalizing such rules is technically impossible. 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 withing certain feature sets. The alternation in (b) does not have this property (for example the change of /ñp/ to [ŋp] 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 → č / __{i,e}, which seems hardly different from k → č / __{i,e}, 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 non-linear 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 suveyed, this is reasonable. There is a bit of danger in assuming that the apparent nonexistence of labial coronalization is an accidental gap, because we don't want to also ignore the nonexistence of the conceivable rule /s,m/→[l,k]/__[w,š] as another accidental gap.

The difference between these two kinds of rules lies in an implicit estimation of how big the gap is between prediction and observation. A number of rules would fall under the rubric 'labial coronalization', which would be formalizable under standard feature theories:

(72) p → č / __ i p,b → č,ǰ / __i
p → č / __i,e p,f,b → č,š,ǰ /__i,e
etc.

If the rules /p/ → [č] / __ [i], /p/ → [č] / __[i,e] and /p,f,b/ → [č,š,ǰ] /__[i,e] were all attested and only the rule /p,b/ → [č,ǰ] / __[i] 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 hundred or so languages that we have looked at, this shouldn't cause serious concern because the chances 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 that a failure to toss a million-sided coin a few hundred times and not have the coin land with side number 957,219 land on top.

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.

We should be a bit more concerned when we identify a somewhat large class — hundreds or perhaps even a thousand — of possible rules which are all unattested and which seem follow a discernable pattern (i.e. "alveopalatalization of labials"). Remember though that we are dealing with a million-sided coin and only a few hundred tosses of the coin. The unattested set of rules represents perhaps a tenth of a percent of the logically possible set, and given the small size of the sample of phonological rules actually available to us, the chances of actually finding such a rule is still not very high.

The situation with the rule /s,m/ → [l,k] / __[w,š] is quite different. This rule is a representative of an 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,š], 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 imagineable arbitrary rules there are. This is why the lack of rules of the type /s,m/ → [l,k] / __[w,š] 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 of phonological theory itself. An analog would be the explanation for why arctic mammals have small furry ears and desert mammals have larger naked ears, proportionate to the size of the animal. There is no independent "law of biology" that states that ear size should be directly correlated with 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 of the domain of phonological theory itself for the lack of labial coronalization in the set of rules 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 → č/ __ {i,e}. In a vast number of languages, there is some degree of fronting of velar consonants to [k^y] before front vowels. The reason for this is not hard to see: canonical velars have a further back tongue position, and front vowels have a further front tongue position. To produce [ki], with a truly back [k] and a truly front [i], the tongue body would have to move forward a considerable distance, essentially instantaneously. This is impossible, and some compromise is required. The compromise reached in 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^yi], which is virtually the same as [ci], with a "true palatal" stop.

The actual amount of consonantal fronting before front vowels that is found in a language may vary from the barely perceivable to the reasonably evident (as in English) to the blatantly obvious (as in Russian). This relatively small physiological change of tongue-fronting has a disproportionately more profound effect on the actual acoustic output. Essentially, a plain [k] sounds more like a [p] that it sounds like [c] ([k] has a lower formant frequency for the consonant release burst), and [c] sounds more like [t] or [č] (in having a higher burst frequency) than it sounds like [k], which it is physiologically more similar to. The acoustic similarity of alveopalatals like [č] and palatals like [c] is great enough that it is easy to confuse one for the other. Thus a child learning a language might (mis)interpret a phonetic alternation [k] ~ [c] as the alternation [k] ~ [č].

Explaining why k → č / __{i,e} *does* exist is a first step in understanding the lack of labial coronalization before front vowels. The next question is whether

there are analogous circumstances under which our unattested rule might also come into existence. Since the production of [p] and the production of [i] involve totally different articulators, a bit of tongue advancement for the production of [i] will have a relatively negligible effect on the acoustics of the release burst for the labial, and especially will not produce a sound that is likely to be confused with [č]. The constriction in the palatal region will be more open for /i/ after the release of /p/, because the tongue does not already produce a complete obstruction in that region (a maximally small constriction) as it does with /k/. It is possible to radically advance the tongue towards the [i]-position and make enough of a palatal constriction during the production of a [p] so that a more [č]-like release will result, but this will not happen simply as a response to a small physically motivated change, as it does with /k/. Thus the probability of such a change — p → č — coming about by phonetic mechanisms is very small, and to the extent that phonological rules get their initial impetus from the grammaticalization of phonetic variants, the chances of ever encountering labial coronalization are slim.

Another approach which might be explored focuses on articulatory consequences of velar coronalization versus labial coronalization. Velar and alveolars involve the tongue as their major articulator, as does [č], whereas labials do not involve the tongue at all. We might then conjecture that there is some physiological constraint that prevents switching major articulators, even in phonological rules. But we *can't* just say that labial never become linguals: they typically do in nasal assimilation. In fact, there is a process in the Nguni subgroup of Bantu languages (Zulu, Xhosa, Swati, Ndebele), where at least historically labials become alveopalatals before *w*, which is very close to the unattested process which we have been looking for. By this process, a labial consonant becomes a palatal before the passive suffix *-w-*, as in the following data from SiSwati.

(73)	*active*	*passive*	*gloss*
	kú-k^{h}ándíŋ-a	kú-k^{h}ándíŋ-w-a	dry roast
	kú-káp^{h}-a	kú-káš-w-a	chop
	kú-k^{x}éb^{h}-a	kú-k^{x}éj-w-a	scrape
	kú-lúm-a	kú-lúñ-w-a	bite
	kú-n|wáb-a	kú-n|wác-w-a	bury

This is a clear counterexample to any claim that labials cannot switch major articulator, and is a rather odd rule from a phonetic perspective (as pointed out by Ohala 1978). Rather than just leave it at that, we should ask how such an odd rule could have come into existence. In a number of Bantu languages, especially those spoken in southern Africa, there is a low-level phonetic process of velarization and unrounding where sequences of labial consonant plus [w] are pronounced with decreased lip rounding and increased velar constriction, so that underlying /pw/ is pronounced as [p^{ɯ}], with [^{ɯ}] notating a semi-rounded partial velar constriction. The degree of velar constriction varies from dialect to dialect and language to

language, and the degree of phonetic constriction increases as one progresses further south among the Bantu languages of the area, so in Karanga Shona, /pw/ is pronounced with a noticeable obstruent-like velar fricative release and no rounding, as [p^{x}]. The place of articulation of the velar release shifts further forward depending on the language and dialect, being realised as [p^{ç}] in Pedi, or as [p^{š}] in Sotho, and finally as [č] in Nguni. So what seems like a quite radical change, given just the underlying-to-surface relation /p/ → [č] in Nguni, is actually just the accumulated result of a number of fortuitously combined, less radical steps.

One of the current debates in phonology — a long-standing debate given new vitality by the increased interest in phonetics — 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-know 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 phonoology for many years.

Further reading

Greenberg 1978, Hale & Reiss 2000, Hume & Johnson 2001, Maddiesson 1984