CHAPTER 2

PHONOLOGICAL PRELIMINARIES

2.1. Introduction

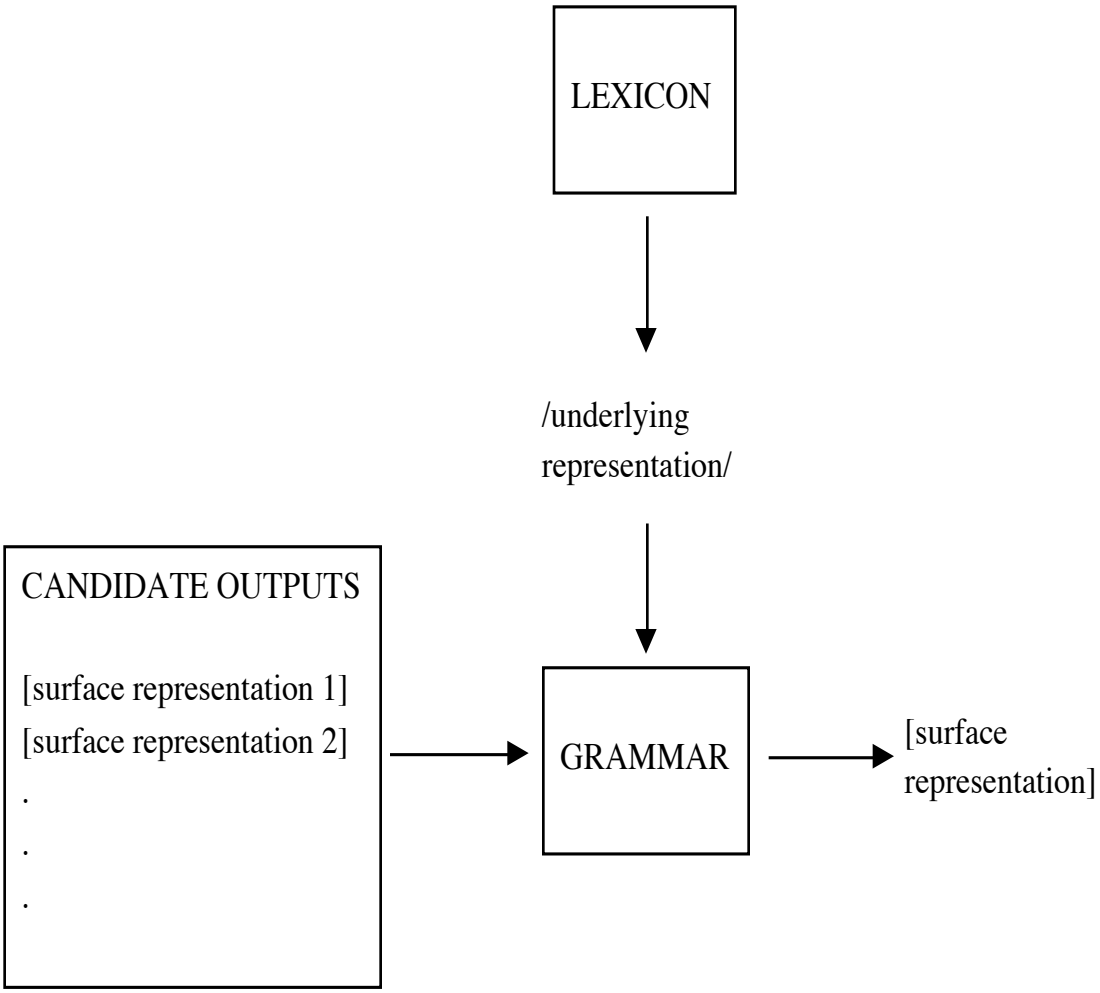
This chapter has two principal aims. The first is to discuss the Optimality Theory view of surface phonotactics in general; the second is to present a specific OT analysis of facts about English syllable onsets that will be used in later chapters. A distinction is drawn between productive *phonological* gaps and nonproductive *lexical* gaps in the syllable inventory. Two examples of phonological gaps ([tl] and [sɹ]) and one example of a lexical gap ([pw]) in the English syllable onset inventory are discussed, and the grammatical groundwork laid for the perceptual studies of later chapters.

2.2. Inventory and phonotactics in Optimality Theory

No spoken language uses all of the segments known to linguistics; each is limited to only a comparatively small inventory (Maddieson 1984, §1.2). Sounds in the inventory do not combine at random to form larger units, but are restricted to a small phonotactically permissible subset of the logically possible combinations.

The OT account of this is shown schematically in Figure 2.1 below. Underlying representations, drawn from the lexicon, are inputs to the grammar. The output of the grammar is the observable set of surface forms.

Figure 2.1 Architecture of the OT phonological model



Under the principle of *Richness of the Base* (Prince & Smolensky 1993, §9.3), the lexicon and the grammar function as independent modules. All they have in common is a representational protocol: The output of the lexicon and the input to the grammar are made of the same representational elements (features, etc.) put together in the same way. Aside from this restriction, the lexicon can, in principle, emit any representation, and the grammar has to deal with it.

Since the set of output candidates includes, at the very least, a fully faithful candidate identical to the input (and is generally held to include *all* of the possible inputs), the

grammar acts as a filter: Some of the inputs from the lexicon result in outputs that are identical to them; others do not.[1]

When we observe that a particular segment (or larger configuration) [Y] is missing from the surface representations of a language, there are therefore two possible accounts: Either no underlying representation /X/ can surface as [Y] because of the filtering action of the grammar, or else there is in principle such an /X/, but by historical accident no one happens to have coined or borrowed a word containing it. In the first case we are dealing with a *phonological* gap; in the latter, with a *lexical* one.

OT is hardly the first theory to make this distinction, and its practical test of what is or is not grammatical remains the same as that of its predecessors: productivity. If native speakers can readily accept and produce an unattested segment in different environments, treating it phonologically and phonetically like a word of their language, then the gap is accidental, and is modelled as a lexical gap. On the other hand, if speakers are consistently unable to produce the segment without alteration and without great effort, then the gap is phonological, and is modelled in OT as a filtering effect of the grammar.

The distinction between phonological and lexical gaps is similar to, but not quite the same as, that between *systematic* and *accidental* gaps. A gap is systematic if it is part of a pattern of gaps; it is accidental if it is isolated. When the aim is to describe the sound pattern of a language with maximum compactness and elegance, it is usual to put the systematic gaps in the grammar and leave the accidental ones out. Starting with the same language, we can arrive at different grammars depending on which criterion we follow, since the systematic gaps are not necessarily productive. (See, for example, the discussion of English initial [ʃl] or [pw bw mw] in §3.1.) Because our psychological claim is specifically about *productive* phonology, we will use the phonological/lexical criterion in constructing our grammar.

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[1] The term "source/filter model" is an analogy with the source/filter model of vocal-tract acoustics, in which the larynx is a sound source whose output is filtered by the rest of the vocal tract. Whatever the larynx emits, the rest of the vocal tract has to deal with it, and will produce some output.

Ideally, an OT grammar for the phonological inventory of a language should make the correct filtering predictions. That is, given the *entire* set of representationally possible underlying representations, it should produce all and only the productive surface forms.

However, this clear theoretical distinction between legal and illegal is often difficult to implement in practice. Algeo (1978), for instance, reviewed 16 "typical" studies of English consonant clusters.

> The sixteen collated studies list a total of 107 possible onset clusters, of which there is agreement on only 30, considerably fewer than a third, leaving 77 onset clusters that are rejected by one or more studies.... The discrepancy is even more striking for coda clusters. The same studies explicitly list or imply well over 500 clusters that are theoretically possible in syllable codas, of which there is agreement on only 19, fewer than 4 percent (p. 208).

Many of the discrepancies are caused by methodological differences – in selection of materials, in choice of transcription, in level of representation (surface or underlying), in choice of phonological domain (syllable or word), and so on, but there is a certain irreduceable gradience, a lack of perfectly sharp demarcation between the "legal" and "illegal" sets. It is agreed that [tl] is an illegal onset and [kw] a legal one, but there is no such uniformity of judgment about [vl] or [pw] – they are felt to lie somewhere in between. The problem of gradient illegality is a difficult one for Optimality Theory, and one which we will return to in our discussion (below, §2.3.2.4) of the [pw bw mw] onsets.

2.3. Inventory and phonotactics of English syllable onsets

Most experiments on phonotactics have exploited the restrictions on place of articulation in English syllable onsets (Massaro & Cohen 1983, Pitt 1998, Moreton 1999),

most often the bans on *[sɹ] and *[tl dl]. The place-of-articulation restrictions are a good choice because they are strongly productive, because ambiguous stimuli are straightforward to synthesize, and because the place features of the critical consonants can be manipulated without changing other linguistic variables.[2]

For these reasons we will concentrate on a grammar of the C[ɹ w l] onsets of American English[3]. We begin by constructing a source-filter account of the stops, affricates, and fricatives found in the onset of a CV syllable, using typologically motivated constraints. This is then extended to the onset of C[ɹ w l]V syllables to account for the phonotactics of *[sɹ], *[tl], and ?[pw]. To anticipate: I will model the *[sɹ] gap as a special case of a general process spreading anteriority and the *[tl dl] gap as a special case of a general ban on homorganic obstruent sequences. The ?[pw] gap, though systematic as a special case of a general ban on homorganic consonant sequences, is not productive and will be modelled as a lexical gap.

§ 2.3.1 lays out the data; § 2.3.2 gives the analysis. § 2.3.2.1 describes the feature system used in this model, based on Hall's (1997) variant of the now-standard Sagey (1990) articulator features. § 2.3.2.2. analyzes CV syllables, § 2.3.2.3. discusses *[sr], § 2.3.2.4. discusses *[tl], § 2.3.2.5. discusses ?[pw]. A summary is given in §3.3.

2.3.1. Explicanda

Their disagreements about other clusters notwithstanding, linguists are in fair agreement on the general outlines of the American English C[ɹ w l] onsets. Table 2.1 shows the onsets which I will treat as the productive ones.

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[2] The other principal restriction is that onsets have to rise in sonority. In theory, manipulating the sonority of either C in a CC onset cluster should affect perception of the sonority of the other C. However, sonority is not a distinctive feature. Two segments which differ in sonority differ in many other linguistically relevant ways as well, making the stimuli hard to construct and the results hard to interpret.

[3] The C[j] onsets I do not discuss, because they have not been used experimentally.

Table 2.1. C[ɹ w l] onsets of American English

Onset		Examples	Hultzén 1965	Woolley 1970	Catford 1988	Hammond 1999
pɹ	bɹ	*prove; brew*	√√	√√	√√	√√
pw	bw	*pueblo; bwana*	√?	√√	??	??
pl	bl	*plant; blame*	√√	√√	√√	√√
tɹ	dɹ	*tread; dread*	√√	√√	√√	√√
tʃɹ	dʃɹ					
tw	dw	*twine; dwindle*	√√	√√	√√	√?
tl	dl		••	••	••	••
kɹ	gɹ	*crack; grid*	√√	√√	√√	√√
kw	gw	*quit; Gwen, guava*	√?	√√	√√	√?
kl	gl	*clean; gleam*	√√	√√	√√	√√
fɹ	vɹ	*free; Wronskian, vroom*	√?	√√	√•	√•
fw	vw		••	••	••	••
fl	vl	*flea; Vladimir*	√•	√•	√•	√?
θɹ	ðɹ	*threw*	√•	√•	√•	√•
θw	ðw	*thwart*	√•	√•	√•	?•
θl	ðl					
sɹ	zɹ		••	••	••	••

Onset		Examples	Hultzén 1965	Woolley 1970	Catford 1988	Hammond 1999
sw	zw	*sweet; Zwicker*	√?	√•	√•	√•
sl	zl	*slot; zloty*	√•	√•	√•	√?
ʃɹ	ʒɹ	*shred; –*	√•	√•	√•	√•
ʃw	ʒw	*Schwinn, Schwartzenegger; –*	?•	√•	••	••
ʃl	ʒl	*schlock; –*	?•	√•	••	?•

Note: (√) indicates that the cited author included the onset without comment. (?) means the author included it, but marked it as marginal. (%) means it was marked as normal for some dialects. (•) means it was not included.

This list is intended to include all and only C[ɹ w l] onsets which can be produced without alteration and without special effort by speakers of American English. Clusters that are obviously non-native have been included as long as they occur in familiar, easily pronounceable names (Schwarzkopf, Zwicker, Vladimir) or loan words (zloty, guava, pueblo)[4]. I am not sure whether the unattested onsets [ʒr ʒw ʒl] (italicized in Table (2)) are a lexical or phonological gap; given the rarity of initial [ʒ] in English, it is dangerous to infer anything from their absence alone. I will take them to be of the same grammaticality as their voiced counterparts.

The transcription in Table (2) is a broad one. The finer phonetic details, which are crucial to this analysis, will be discussed below.

[4] Compare news broadcasters' fluent pronunciations of *zloty*, *Norman Schwarzkopf*, *Vladimir Putin* with their awkward *Chechnya* and *Srebrenica*. The productivity of the syllable-initial [nj] and [sɹ] gaps for these trained speakers is clearly audible.

2.3.2. Analysis

Two generalizations are immediately clear from Table (2). First, the C in the C[ɹ w l] cluster is itself never a [ɹ w l], but is always something of lower sonority. This is a special case of a general fact, true across languages, about syllable onsets – that sonority rises over the course of the onset (Clements 1990).[5] Second, there is no difference between the behavior of unvoiced C and its voiced counterpart.

Since both of these issues are irrelevant to the question of place restrictions, we can simplify our task by ignoring them. Henceforth we will only consider voiceless Cs, letting them do double duty for their voiced counterparts, and ignore candidates with flat or falling sonority (assumed to be ruled out by very high-ranked markedness constraints).

2 3.2.1. Representations

I adopt the representational system below. It is a slightly simplified version of the system proposed by Hall (1997), which is in turn a modification of the Sagey (1990) feature geometry based on active articulators.

[5] English, like a number of other languages, allows [s] and perhaps [S] to occur out of the expected sonority sequence (e.g., spit, stick, skip, square; shtik). This is a vexed question which I will not discuss. It has been suggested that the [s]C sequence is a complex segment like a reverse affricate (Hayes 1980, Lamontagne 1993).

(2.2) Feature tree

- +Root
  - +Manner
    - continuant
    - consonantal
    - sonorant
    - strident
    - +lateral
  - +Laryngeal
    - spread glottis
    - constricted glottis
    - voiced
  - +Supralaryngeal
    - +Velum
      - nasal
    - +Place
      - +Labial
        - +round
      - +Coronal
        - anterior
        - distributed
        - back
      - +Dorsal
        - back
        - high
        - low

Note: Features marked '+' are privative; others are equipollent.

The most notable difference between this and the familiar Sagey (1990) system is that [back], normally a dependent of the Dorsal articulator, is here also a dependent of the Coronal node too, with the stipulation that [+back] requires [+Dor]. The innovation is Hall's (1997) solution to a problem in the original system: that palatalization could not be straighforwardly modelled as feature spreading when the palatalized consonant was [+Cor]. Segments which triggered palatalization, usually front vowels, were [+Dor –back], but the [–back] could not be spread to a preceding [+Cor] segment, since [+Cor] could not support it (see Sagey 1990: §3.4.2.2). Hall argues that the palatalization feature, whatever it is, must be a child of both the Coronal and Dorsal articulator nodes, since it can be spread to both [s] and [x]. The segments triggering palatalization or resulting from it are, he says, all characterized by a fronted tongue body, which is the articulatory correlate of [–back].

Allowing both tongue nodes to sponsor [–back] captures the physical link between the lamina and the forepart of the dorsum (Hall 1997:§2.7.2).

It is crucial to the analysis to have *some* representational scheme under which [j ɹ] can spread something to the Coronal node and [w] cannot; I have chosen this one because of Hall's detailed treatment of the various places of articulation.

I have also simplified Hall's feature tree by leaving out his Peripheral node, which came below Place and above {Labial, Dorsal}, by replacing the Laryngeal features [stiff] and [slack] with [voiced], and by omitting [rhotic] in favor of [+high, +low] (see below). The Tongue Root node has been removed; I will ignore the complexities of uvular, pharyngeal, and laryngeal consonants (McCarthy 1991). None of these changes is crucial to the analysis.

With two exceptions, all features in this system are either privative or equipollent. A privative feature is either present or it is not. An equipollent feature is either [+F] or [–F], but not both. If a feature is present in a representation, then all equipollent children of that feature have to be present as well, with either + or – specification. That is, an equipollent feature can be absent from the representation of a segment only if the feature's parent is also absent. A segment consisting only of the features [+Root +Laryngeal] is possible, but one which is [+Cor] must be either [+ant] or [–ant].

The two exceptions are [cont] and [strident]. Affricates are analyzed as [–cont +cont] (Sagey 1990:§3.3.4.2). The feature [strident] is an equipollent child of the Manner node, but it is only present when the segment is a fricative or affricate, and only for [+Lab] or [+Cor] segments.

Finally, I have left the privative [+lateral] under the Manner node because it behaves like a Manner feature in not spreading. The other obvious option is to put it under [+Cor], since nearly all known laterals are coronal and they occur at all four coronal places of articulation (McCarthy 1988, Hall 1997: §A.2.3.2). There are lateral fricatives, lateral flaps,

and (most commonly) lateral affricates. None is found in English. Evidence for how they are repaired is lacking, so will not discuss them here.

2.3.2.1.1. Consonant features

The source-filter model is responsible for explaining the badness of a great many candidates for the C in a C[ɹ w l] onset. Here, the critical candidates are the oral stops, affricates, and fricatives at every place of articulation. Their representations are shown in Tables 2.3 and 2.4.

Table 2.3. Obstruent manner features

Manner	Oral stops	Affricates	Fricatives
cont	–	+ and –	+
cons	+	+	+
son	–	–	–
strident	(never)	(some)	(some)

Table 2.4. Obstruent place features

a.

Place		Labials, labiodentals	Dentals	Alveolars	Retroflexes
+Lab		+			
	round				
+Cor			+	+	+
	ant		+	+	–
	dist		(+)	–	–
+Cor/+Dor					
	back				
+Dor					
	high				
	low				

b.

Place		Palatoalveolars, alveolopalatals	Palatals	Velars
+Lab				
	round			
+Cor		+		
	ant	–		
	dist	+		
+Cor/				
+Dor				
	back	–	–	+
+Dor			+	+
	high		+	+
	low		–	–

The IPA distinguishes palatoalveolar from alveolopalatal, at least for fricatives. I accept Hall's arguments (1997: §2.5.2) that the two should not have different features, since no language has two contrasting segments distinguished only by that place difference.

Table 2.5 shows the IPA symbols for every combination of the manners from Table 2.3 with the places from Table 2.4, together with stridency values for the fricatives and affricates.

Table 2.5. Representation of consonants.

	Stop	Affricate	Fricative	[strident][6]
Labial	p	pɸ	ɸ	–
Labiodental	p̪	pf	f	+
Dental/Interdental	t̪	t̪θ	θ	–
Alveolar	t	ts	s	+
Retroflex	ʈ	ʈʂ	ʂ	+
Palatoalveolar, alveolo-palatal	ʧ	tʃ, tɕ	ʃ, ɕ	+
Palatal	c	cç	ç	–
Velar	k	kx	x	–

These are the low-sonority voiceless segments which this system is capable of representing. In our source-filter model, the lexicon can emit any of them.. Since most of these segments do not and cannot occur in English, we will have to build a grammar which deletes the un-English ones or converts them into English segments.

2.3.2.1.2. Features of [ɹ w l]

Our task in this section is simply to describe the surface features of American English [ɹ w l]. We will not explain *why* these segments, rather than other sonorants, should be in the AmEng inventory. I adopt the analysis of Kahn (1980), who makes [ɹ w] glides (semivowels) and [l] a sonorant consonant.

[6] I do not know anything about the stridency of lateral fricatives. In the absence of better information, I will assume that they are as strident as the corresponding non-lateral fricatives.

Guenter (2000) summarizes the arguments that American English [ɹ w] are glides as follows: (1) They are phonetically central approximants. (2) They restrict the set of vowels that can precede them. (3) Each has a stressed syllabic version with which it alternates. (4) They cannot occur after tautosyllabic diphthongs (Cohn & Lavoie 2000). (5) Flaps occur after them. (6) Final [t d] cannot be deleted after them. These statements are in general not true of [l].[7]

Kingston (p.c.) points out that stops are often intruded between [l] and a following lingual fricative: *pulse* [pʌlts], *filth* [fɪltθ]. The same phenomenon occurs with the other class of high-sonority consonants, the nasals: *warmth* [wɔɹmpθ], *chance* [tʃænts]. It does not happen after [j ɹ w].

We will model [ɹ w] as glides – that is, as vowels syllabified into a syllable onset, having the same features as the syllabic [ɹ u] (Hall 1997:135, Rosenthall 1997). The proposed feature system is shown in Tables 2.6 and 2.7.

Table 2.6. Manner features for [ɹ w]

Manner	[ɹ]	[w]
continuant	+	+
consonantal	–	–
sonorant	+	+
strident		

[7] However, Guenter did find that 15 of his 16 informants had an [l] that satisfied (4), and many had one that satisfied (3); he interprets this as evidence of language change in the direction of a glided [l].

Table 2.7. Place features for [ɹ w]

Place		ɹ	w
+Lab		+	+
	round	+	+
+Cor		+	
	ant	–	
	dist	– or +	
+Cor/ +Dor			
	back	+	+
+Dor		+	+
	high	+	+
	low	+	–

The manner features are standard, as are the place features for [w][8] . Those for [ɹ] require some justification.

Delattre and Freeman (1968) made X-ray films, with synchronized spectrograms, of 46 speakers from various parts of the United States. They found a wide variety of [ɹ] articulations, which sounded very similar. All speakers, in all syllable positions, make a constriction in the pharynx about halfway between the glottis and the uvula. They also make a constriction somewhere in the oral cavity between the corner of the alveolar ridge and the beginning of the soft palate, using the dorsum, blade, or tip of the tongue – in onsets, always the blade or tip. The lips are rounded (most strongly in the onset of a stressed syllable). Similar results were obtained in MRI and palatographic studies of 4 speakers by Alwan et al. (1997).

[8] Hall argues that both [j ɹ] are actually [+Cor] (1997:§§1.2.6, 4.4).

In vowels, a pharyngeal constriction is the articulatory correlate of [+low]; a close oral constriction, that of [+high].. From an articulatory-phonetic standpoint, all varieties of American English [ɹ] are therefore [+low +high][9]. The formal advantages are clear: we are rid of the [+rhotic] feature (which needed the same kind of co-occurrence stipulations as [+lateral]), and we no longer have to stipulate that [+high +low] is impossible.

In the studies of Delattre & Freeman (1968) and Alwan et al. (1997), the tongue tip or blade participated in all versions of the onset glide [ɹ], indicating that the glide was coronal[10]. The position of the constriction ranged from prepalatal to postpalatal. We can model it as [+Cor –ant] and either [+dist] or [–dist] depending on the speaker. Since the choice is not crucial to the analysis, I will favor my own speech and pick [+dist].

Finally, lip-rounding in all positions requires that [ɹ] be modelled as [+Lab +round].

For [l], we use the features of Tables 2.8 and 2.9:

Table 2.8. Manner features for [l]

Manner feature	[l]
continuant	–
consonantal	+
sonorant	+
strident	
+lateral	+

[9] Delattre & Freeman's Figure 1, a gallery of X-ray tracings, shows this very clearly. Their "Type 4" syllabic [ɹ] is particularly striking – the tongue has two humps, one in the middle pharynx and one under the hard palate, with a deep indentation between them, like the back of a weasel.

[10] The nuclear [ɹ] had a coronal component in only one of its five manifestations (there was much more variety between speakers in non-initial position), with the blade approaching the rear of the hard palate (Delattre & Freeman's Figure 1, Type 5). It seems that coronal articulations are obligatory in syllable onsets, but (for most speakers) prohibited in syllable nuclei.

Table 2.9. Place features for [l]

Place		[l]
+Lab		
	round	
+Cor		+
	ant	+
	dist	–
+Cor/ +Dor		
	back	+
+Dor		+
	high	+
	low	–

The manner features are standard except for [–cont]. It is a matter of debate whether [l] is continuant phonetically or phonologically.

The double articulation of [l] has been shown by Sproat & Fujimura (1993). Their X-ray microbeam data, from four speakers of American English, found both a dorsal and an apical gesture, whose relative timing varied depending on prosodic position. The apical gesture we model as [+Cor +ant -dist]. The MRI and palatographic study of Narayanan et al. (1997) confirmed the double gesture, and showed that the apical gesture contacted the alveolar ridge along the midline in both onset and coda [l].

2.3.2.2. CV syllables

The inventory of consonants in C onsets, shown in Table 2.9, can be summed up as follows:

1. Two classes do not occur at all: the retroflexes and the palatals. Both of these are rare (marked) places of articulation cross-linguistically. 2. There is a stop series labial–alveolar–velar beside a single palatoalveolar affricate. This is a single [–cont –son] series, labial–alveolar–palatoalveolar–velar, with affricate manner obligatory at the palatoalveolar place and forbidden elsewhere. 3. There is a fricative series labial–dental–alveolar–palatoalveolar. Velar fricatives are forbidden.

Table 2.10 shows the repair which I assume is made to each of the impermissible segments: A box encloses each group of underlying segments that map onto the same surface segment.

Table 2.10. English surface obstruent inventory in CV syllables

Place of articulation	Stop	Affricate	Fricative	[strident]
Labial	p	pɸ	ɸ	–
Labiodental	p̪	pf	f	+
Dental/Interdental	t̪	t̪θ	θ	–
Alveolar	t	ts	s	+
Retroflex	ʈ	ʈʂ	ʂ	+
Palatoalveolar, alveolopalatal	t̠	tʃ, tɕ	ʃ, ɕ	+
Palatal	c	cç	ç	–
Velar	k	kx	x	–

Note: The white segments are found in surface CV environments. Underlying gray segments are mapped to the white segment in the same enclosing box.

The process involves 24 underlying-to-surface mappings, and the grammar I propose will be quite complex, with 12 constraints ranked in 9 strata. I will first describe and justify the constraints, then present ranking arguments for them.

2.3.2.3.1. Undominated faithfulness constraints

None of the repairs shown in Table 2.10 involve deleting the offending segment entirely. This is very naturally modelled as an all-dominating faithfulness constraint against deletion:

(2.11) MAXSEG
Every segment of the input has a correspondent in the output.

No repair involves changing the major articulator: Labials are changed to labials, coronals to coronals, and dorsals to dorsals. This can be modelled with an IDENT constraint:

(2.12) IDENT[PLACE]
If an underlying and a surface segment are in correspondence, they share the same major articulator.

2.3.2.3.2. Coronal stop places: dental, retroflex, alveolar, and palato-alveolar

Of the four coronal stop places, only the alveolar is used in English CVs. Instead of a stop, the palato-alveolar place has an affricate.

The lack of retroflex and dental stops can be seen as the result of high-ranked markedness constraints against them, constraints whose existence can be justified typologically.

Retroflexes are banned in many languges besides American English. In Maddieson's genetically and geographically balanced sample of 317 languages, over 99% had a dental or alveolar stop, while only 11.4% had a retroflex stop (1984: §2.4). In the same sample, 266 languages (84%) had a non-retroflex voiceless fricative, while only 17 (5.4%) had a retroflex voiceless fricative. For voiced fricatives the numbers were 96 (30%) and 3 (1.0%) respectvely (1984: Table 3.2). The markedness of retroflexes can be

modelled by a markedness constraint *RET, which awards one mark for each segment that is [–ant, –dist].

(2.13) *RET
*[–ant, –dist]

It is unusual for a language to contrast dental and alveolar place; the [+anterior] stops are either laminal or apical. The dental stops [t̪ d̪] I assume are ruled out by a blanket constraint against the dental place of articulation, operative in other languages which favor alveolar over dental place.

(2.14) *DENTAL
*[+Cor +ant +dist]

On the basis of loan-word phonology, I will assume that both retroflexes and dentals are repaired to alveolars. Alveolars remain alveolar, and palato-alveolars remain palato-alveolar (though, for reasons discussed in the next section, palato-alveolar stops gain a [+cont] specification to become affricates).

Table 2.15. Repair of retroflexes to alveolars (Yule & Burnell 1886, *American Heritage Dictionary* 2000)

Source language	Original form	English
Tamil	[kaʈʈumaram]	*catamaran*
Hindi	[ɖakait]	*dacoit*
Hindi	[paʈʈiː]	*puttee*
Hindi	[ʈopiː]	*topee*
Hindi	[ʈamʈam]	*tom-tom*
Hindi	[luːʈ]	*loot*

Table 2.16. Repair of dentals to alveolars (*American Heritage Dictionary* 2000)

Source language	Original form	English
French	[d̪ɛbakl]	*debacle*
French	[t̪ulɔ̃]	*Toulon*
Russian	[t̪okamak]	*tokamak*

The repairs involve changing the [anterior] and [distributed] specifications. The problem is how to insure that palato-alveolar inputs, and only palato-alveolar inputs, surface as palato-alveolar outputs. The solution is to hand: Under the Hall (1997) feature system, palato-alveolars are both coronal and dorsal. Changing a non-palato-alveolar to a palato-alveolar, or vice versal, therefore violates the undominated IDENT[PLACE]. Since *RET and *DENTAL force retroflexes and dentals to change, while IDENT[PLACE] prevents them from becoming non-coronals or palato-alveolars, their only recourse is to become alveolars by changing their values of [ant] or [dist].

(2.17) IDENT[PLACE] » *RET, *DENTAL » IDENT[ANT], IDENT[DIST].

	IDENT [PLACE]	*RET	*DENTAL	IDENT[ANT]	IDENT[DIST]
/d̪/ [d̪][11]			*!		
☞ [d]					*
[ɖ]		*!		*	*
[dʒ]	*!			*	
/d/ [d̪]			*!		*
☞ [d]					
[ɖ]		*!		*	
[dʒ]	*!			*	*
/ɖ/ [d̪]			*!	*	*
☞ [d]				*	
[ɖ]		*!			
[dʒ]	*!				*
/ɖ/ [d̪]	*!			*	
[d]	*!			*	*
[ɖ]	*!				*
☞ [dʒ]					

2.3.2.3.3. The persistence of [θ]

[11] [d̪] represents a [–ant, +dist] (palatoalveolar) stop, the stop corresponding to the affricate [tʃ].

The fricatives [θ ð] are the only dental segments in English CVs, and the only [–strident] fricatives. As such, they seem to be resistant to two markedness constraints.

One, discussed in the previous section, is *DENTAL, which militates against all dental articulations.

The other is a constraint against non-strident fricatives. English is rich in [+strident] fricatives ([f s ʃ]) and poor in [–strident] ones (only the comparatively rare [θ]). The situation is the same in most languages. The three most common fricative places (voiced or voiceless) are, in descending order, [s]/[s̪], [ʃ], and [f]. The first nonstrident fricative, in fourth place, is [x], which is half as common as [f] and more than twice as common as any other nonstrident fricative (Maddieson 1984: Table 3.2). We can capture the markedness of nonstridents directly as a constraint against [–strident]:

(2.18) *[–STRIDENT]

I will analyze the persistence of [θ] in English as preservation of the salient acoustic contrast between the [–strident] [θ] and the other, [+strident], coronal fricatives[12]:

(2.19) MAX[–STRIDENT]/COR

An underlying [–strident] coronal must correspond to a surface [–strident] coronal.

(2.20) MAX[–STRIDENT]/COR » *[–STRIDENT]

/θɪk/	MAX[–STRIDENT] / COR	*DENTAL	*[–STRIDENT]	IDENT[DIST]
[θɪk]		*	*	

[11] Since stops are not specified for [strident], this constraint also keeps [tθ θ] from turning into stops.

[sɪk]	*!			*

Since all the other [–strident]s (the labials and dorsals) are still able to change to less marked segments, they will do so, while the dentals cannot:

(2.21)

/ɸæt/	MAX[–STRIDENT] /COR	*[–STRIDENT]	(lower-ranked faithfulness)
[ɸæt]		*!	
[fæt]			*

This leaves the dental fricatives as the only possible dentals and the only possible non-strident fricatives.

2.3.2.3.4. Dorsal places of articulation: palatals and velars

English CVs have only velar articulations.[13] Palatals are repaired to velars.

Palatals are rare cross-linguistically. Maddieson found palatal or palatoalveolar stops in only 18.6% of his sample, though over 99% had a velar stop (1984: §2.4). A voiceless palatal fricative occurred in only 16 of the languages, or 5.0%, and a voiced palatal fricative was found in only 7, or 2.2%. By way of comparison, voiceless and voiced palatoalveolar fricatives turned up in 146 (46%) and 51 (16%) (Maddieson 1984: Table 3.2). We capture this with another context-free markedness constraint, *PAL, which gives a mark to each [+Dor –back] consonant.

(2.22) *PAL
*[+cons, +Dor, –back]

[12] The allophonically palatalized velars found before front vowels, as in key, are not as far fronted as phonemic palatals in languages that have them (Keating & Lahiri 1993). We regard them here as velars.

This constraint will cause underlying palatals to become velars (violating low-ranked IDENT[BACK], but satisfying high-ranked IDENT[PLACE]):

(2.23) IDENT[PLACE] » *PAL » IDENT[BACK]

/ca/	IDENT[PLACE]	*PAL	IDENT[BACK]
[ca]		*!	
☞ [ka]			*
[ta]	*!		

Since palato-alveolars are also dorsal and [–back], they meet the structural description of *PAL. However, IDENT[PLACE] protects them from losing their [Cor] specification:

(2.24)

/tʃa/	IDENT[PLACE]	*PAL	IDENT[BACK]
[ca]	*!	*	
[ka]	*!		*
☞ [tʃa]		*	

2.3.2.3.5. Labial places of articulation: bilabials and labiodentals

Since no language is known to contrast bilabial and labiodental stops, they are not distinguished in the Hall (1997) feature system.

Bilabial and labiodental fricatives are featurally distinct, the bilabials being [–strident] while the labiodentals are [+strident]. The result of this, as we saw in (2.21), is that [ɸ] is converted to [f] in order to satisfy *[–STRIDENT].

2.3.2.3.6. The stop-affricate-fricative series

It is very common for languages to have affricates at all and only those places where it has no stops. The most common pattern – found by Maddieson in 86 out of 317 languages, or 27% – is the English one of stops at the labial/alveolar/velar places and affricates at the palatoalveolar place (Maddieson 1984: § 2.5). The effect of this is to disperse the [–cont] segments as widely as possible in articulatory and acoustic space, with one segment being made by the lips, one by the tongue tip, one by the tongue blade, and one by the dorsum.

Affricates are, typologically, more marked than fricatives, which are more marked than stops. Every one of the languages in Maddieson's sample had stops, and most had two stop series. All of the 451 languages in the UPSID database have stops; 413 have fricatives; only 300 have affricates.

However, it seems that the palatoalveolar place of articulation is more hospitable to affricates than to stops. Maddieson's Tables 2.5 and 2.8 make this clear:

Table 2.25. Number of languages with stops at given places in the sample of Maddieson (1984:Table 2.5).

	Bilabial	Dental or alveolar	Palatal or palato-alveolar	Retroflex	Velar	Uvular	Labial-velar
No. of languages	314	316	59	36	315	47	20
Percent	99.1%	99.7%	18.6%	11.4%	99.4%	14.8%	6.3%

Table 2.26. Frequency of the most common affricates in the sample of Maddieson (1984:Table 2.8).

Voicing	Dental/alveolar[14]		Palato-alveolar	
Plain voiceless	/*ts/	95	/tS/	141
Aspirated voiceless	/*ts^{h}/	33	/tS^{h}/	42
Plain voiced	/*dz/	30	/dZ/	80

The cross-linguistic pattern is that found in English, where the palato-alveolar position in a stop series is filled with an affricate. Affricates are more marked than stops, except at the palato-alveolar place, where the opposite is true. The affricate, it appears, is the stop of the palato-alveolar place. This tendency can be formalized as a markedness constraint:

(2.27) AFFR/PALAL
An obstruent should be an affricate if and only if it is palato-alveolar.

In English, illegal labial and alveolar affricates are repaired by converting them into fricatives: *pfennig* [f], *tsunami* [s], *Zeitgeist* [z], *czar* [z] (Jones 1997). The illegal palatoalveolar stops are repaired by affricating them: *Magyar* [dʒ]. The two processes are shown in Table 2.28:

[13] Maddieson's * indicates "dental or alveolar (combined)". The non-IPA symbols are Maddieson's.

Table 2.28. Labial, alveolar, and palatoalveolar series of American English

	[–cont]		[–cont +cont]		[+cont]
Labial	p		pf	□	f
Alveolar	t		ts	□	s
Palatoalveolar	t̠	□	tʃ		ʃ

Note: The grayed segments are abset from the surface inventory. The repair to each is indicated by the arrow.

In the labial and alveolar cases, the marked affricate is deaffricated to a fricative by deleting [–cont], rather than to a stop by deleting [+cont]. Some faithfulness constraint must be blocking the deletion of [+cont] but not of [–cont]. We will take it to be MAX[+CONT], which gives a mark to each corresponding segment pair where the underlying segment has [+cont] but the surface segment does not:

(2.29) MAX[+CONT]
An underlying [+cont] segment must correspond to a surface [+cont] segment.

Since the non-palato-alveolar affricates lose their [–cont] specification in order to satisfy AFFR/PALAL, it must be ranked above MAX[–CONT]:

(2.30) MAX[–CONT]
An underlying[–cont] segment must correspond to a surface [–cont] segment.

(2.31) MAX[+CONT], AFFR/PALAL » MAX[–CONT]

/pfɛnɪk/	MAX[+CONT]	AFFR/PALAL	MAX[–CONT]
[pfɛnɪk]		*!	
[pɛnɪk]	*!		
☞ [fɛnɪk]			*

The palato-alveolar stops change manner rather than place of articulation so as not to violate the undominated IDENT[PLACE]. (The palato-alveolar place is the only one which is both coronal and dorsal, so that any change of place changes a major articulator.) They become affricates, rather than fricatives, to avoid a gratuitous MAX[–CONT] violation.

(2.32)

	/maḑar/	IDENT[PLACE]	AFFR/PALAL	MAX[–CONT]
	[maḑar]		*!	
	[madar]	*!		
☞	[madʒar]			
	[maʒar]			*!

MAX[+CONT] is violated when [ç] or [x] is repaired to [k], so it must be dominated by *PAL, *[–STRID].

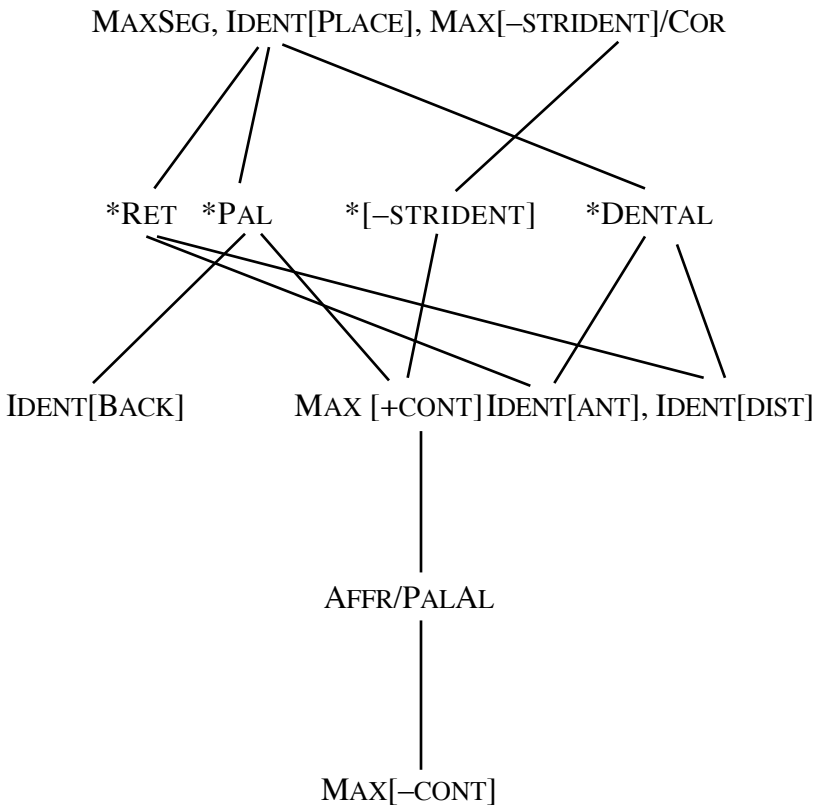
(2.33) *PAL, *[–STRID] » MAX[+CONT]

	/aıçman/	*PAL	*[–STRID]	MAX[+CONT]
	[aıçman]	*!	*	
	[aıxman]		*!	
	[aıcman]	*!		
☞	[aıkman]			*

2.3.2.3.7. Constraint lattice

The grammar we have established has the rankings shown in (2.34). The topmost stratum consists of unviolated faithfulness constraints. Lines represent rankings established by direct comparison in ranking arguments.

(2.34)



2.3.2.3. *[sɹ]

With the basic inventory accounted for, we are now ready to turn to the first of the two onset conditions used in the experiments. Table 2.10, repeated here, can be compared with Table 2.35, which shows the observed inventory and repairs in C[ɹ]V syllables.

Table 2.10. English surface obstruent inventory in CV syllables

Place of articulation	Stop	Affricate	Fricative	[strident]
Labial	p	pɸ	ɸ	–
Labiodental	p̪	pf	f	+
Dental/Interdental	t̪	t̪θ	θ	–
Alveolar	t	ts	s	+
Retroflex	ʈ	ʈʂ	ʂ	+
Palatoalveolar, alveolopalatal	t̠	tʃ, tɕ	ʃ, ɕ	+
Palatal	c	cç	ç	–
Velar	k	kx	x	–

Note: The white segments are found in surface CV environments. Underlying gray segments are mapped to the white segment in the same enclosing box.

Table 2.35. English surface obstruent inventory in C[ɹ]V syllables

Place of articulation	Stop	Affricate	Fricative	[strident]
Labial	p	pɸ	ɸ	–
Labiodental	p̪	pf	f	+
Dental/Interdental	t̪	t̪θ	θ	–
Alveolar	t	ts	s	+
Retroflex	ʈ	ʈʂ	ʂ	+
Palatoalveolar, alveolopalatal	t̠	tʃ, tɕ	ʃ, ɕ	+
Palatal	c	cç	ç	–
Velar	k	kx	x	–

Note: The white segments are found in surface CV environments. Underlying gray segments are mapped to the white segment in the same enclosing box.

The only differences between permissible Cs in CV and C[ɹ]V syllables are in the coronals. Four formerly separate groups have been merged into two, so that all coronals (except [θ], immune as usual) have the same minor place features: [–ant +dist –back]. Since these are exactly the coronal features of [ɹ], the merger is naturally understood as place assimilation via spreading of the Coronal node.[15]

[14] The phonetic effect of [ɹ] on preceding /t/ is variously described by different authors. I discuss here the dialect of Hammond (1999:101) and myself, in which the pre–[ɹ] /t/ have a distributed palato-alveolar articulation, [tʃ]. Others, such as Olive et al. (1993), say that the articulation is an apical, retroflexed [ʈ]. Given the wide variation in how speakers articulate [ɹ], the difference may be due to the spread of different features: the first [ɹ] being [–ant, +dist] and the second being [–ant, –dist]. If so, one would expect that [ʈɹ] speakers would have a retroflex, rather than a palato-alveolar, articulation for /ʃɹ/, so that it would be pronounced [ʂɹ]. The acoustic contrast between [t] and [ʈ], or between [s] and [ʂ], will in any case be difficult to hear before [ɹ] owing to the muffling effect of lip rounding and the lowering of formant frequencies.

(2.35) SPREAD[COR]
Neighboring [+Cor] segments should have the same value of [ant], [dist], and [back].

SPREAD[COR] must dominate the faithfulness constraints against spreading the minor coronal features: IDENT[ANT] and IDENT[DIST]. No IDENT constraint on [back] is violated since coronals either lack a [back] node entirely or are [–back]. Since [θ] is immune, SPREAD[COR] must be dominated by MAX[–STRIDENT]/COR.

(2.36) MAX[–STRIDENT]/COR » SPREAD[COR] » IDENT[ANT], IDENT[DIST]

a.

/sɹɛbɹɛnitsɑ/	MAX [–STRIDENT] / COR	SPREAD [COR]	IDENT[ANT]	IDENT[DIST]
[sɹɛbɹɛnitsa]		*!		
[ʃɹɛbɹɛnitsa]			*	*

b.

/θɹɛd/	MAX [–STRIDENT] / COR	SPREAD [COR]	IDENT[ANT]	IDENT[DIST]
[θɹɛd]		*		
[ʃɹɛd]	*!		*	

The illegality of [sɹ] arises from its failure to obey SPREAD[COR]: The [s] should be retracted to [ʃ], but is not.

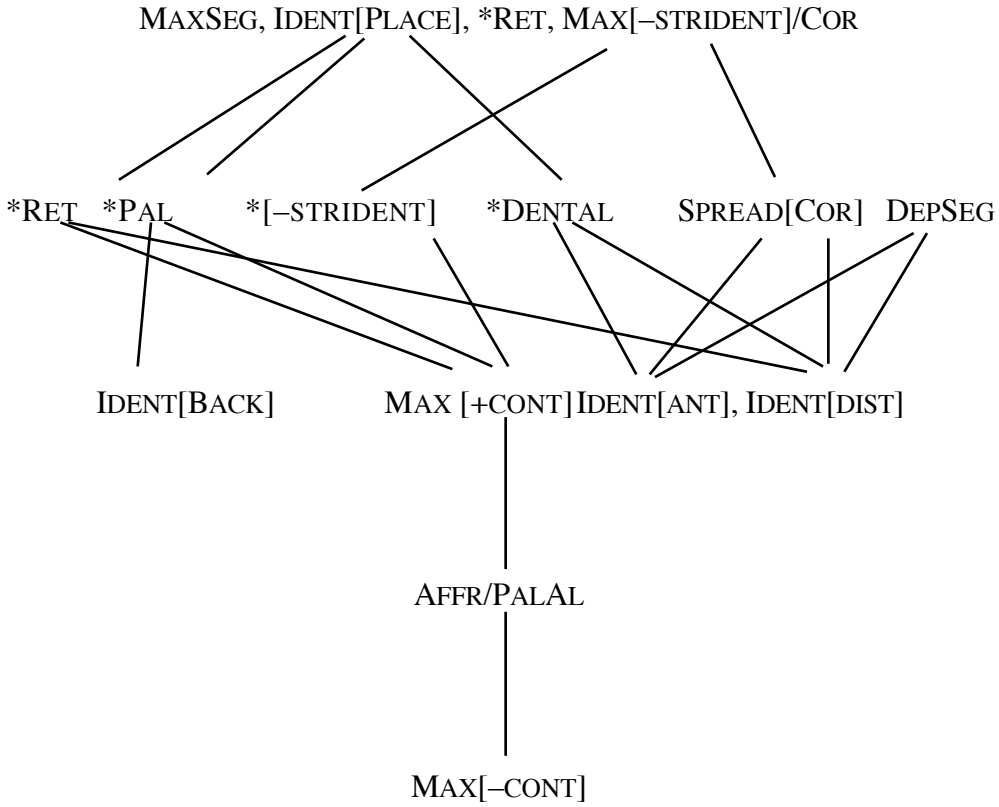
A conceivable repair to [sɹ] which is not in fact used is epenthesis; *Sri Lanka* does not become [səɹi] *Lanka* the way that *tmesis* becomes [təmisɪs]. This shows that the anti-epenthesis constraint DEPSEG dominates IDENT[ANT] and IDENT[DIST]:

(2.37)

	/sɹi/	SPREAD [COR]	DEPSEG	IDENT[ANT]	IDENT[DIST]
	[sɹi]	*!			
	[ʃɹi]			*	*
	[səɹi]		*!		

The resulting grammar is shown in (2.38):

(2.38)



2.3.2.4. *[tl]

The second commonly-used environment is the C[l]V syllable. Here, all of the coronals are excluded from appearing in C position except the strident fricatives.

Table 2.39. English surface obstruent inventory in C[ɹ]V syllables

Place of articulation	Stop	Affricate	Fricative	[strident]
Labial	p	pɸ	ɸ	–
Labiodental	p̪	pf	f	+
Dental/Interdental	t̪	t̪θ	θ	–
Alveolar	t	ts	s	+
Retroflex	ʈ	ʈʂ	ʂ	+
Palatoalveolar, alveolopalatal	t̠	tʃ, tɕ	ʃ, ɕ	+
Palatal	c	cç	ç	–
Velar	k	kx	x	–

Note: The white segments are found in surface CV environments. Underlying gray segments are mapped to the white segment in the same enclosing box. The repair for [tl] is shown as [k], but this is not known with certainty.

The illegality of [tl dl] in an onset can be linked to the fact that both are coronal and [–cont], through the Relativized Obligatory Contour Principle (Selkirk 1991, Padgett 1991):

(2.40) *Relativized OCP* (Selkirk 1991)

G	H	
|	|	where G and H share property F, and are F-wise
*F	F	adjacent.

The Relativized OCP is a feature-geometric constraint designed to account for root co-occurrence restrictions in which the effects of place of articulation similarity are

modulated by stricture features. In Modern Standard Arabic, for example, a triconsonantal verb root may contain two successive coronals, but only if they disagree in continuity. Thus /sVtVq/ is permissible, but /sVθVq/ or /tVdVq/ is not (Yip 1989). However, there are no general restrictions on co-occurrence of two coronals, or on co-occurrence of two [+cont] or [–cont] consonants; what is discouraged is similarity on both dimensions at once. Segments which are too different in stricture do not interact in place. (In feature-geometric terms, stricture similarity is expressed as adjacency on an autosegmental tier.)

The effect of the Relativized OCP can be seen diachronically in English, in the progressive loss of the coronal [j] in onsets after coronals and before [u]. It was first lost from [rju], as in *rude, rule*, then from [lju] as in *lute, dilute*, and is now being dropped from [nju] (*news*), [sju] (*suit*), and (in the most advanced dialects) [dju] and [tju] (*duke, tune*) (Trudgill 1999:56-59). The more similar the preceding consonant is to [j] in stricture, the earlier it was lost.

We can see the ban on [tl dl] as a similar phenomenon. English allows [pl bl kl gl], where the place of articulation differs between stop and liquid even though both are noncontinuant. It allows [t̪ɹ d̪ɹ] and [sl], where both segments are coronal but only one is a non-continuant. What is forbidden is two successive consonants with the same articulator and the same value of [cont]: [tl dl]. This is modelled as one of the family of Relativized OCP constraints:

(2.41) OCP(CONT, PL)
Adjacent consonants using the same articulator are forbidden if they share the same value of [cont].

There is little evidence as to the nature of the repair to the illegal sequence. It is possible that /tl/ is repaired by epenthesis, or by making the [l] syllabic, and thereby separating its coronal articulation from the [t] (Sproat & Fujimura 1993). Another possibility is that the /t/ is realized as [k], as in the attested pronunciation [klɪŋgɪt] for

Tlingit[16]. It has been shown that French listeners strongly tend to misperceive the illegal [t̪l] as [kl] (Hallé et al. 1998).

The place-dissimilation repair would require the anti-epenthesis constraint DEPSEG to dominate IDENT[PLACE]. The epenthesis repair would require the opposite.

(2.42) OCP(CONT, PL), DEPSEG » IDENT[PLACE]

/tlŋgɪt/	OCP(CONT,PL)	DEPSEG	IDENT[PLACE]
[tlŋgɪt]	*!		
[təlŋgɪt]		*!	
☞ [klŋgɪt]			*

(2.43) OCP(CONT, PL), IDENT[PLACE] » DEPSEG

/tlŋgɪt/	OCP(CONT,PL)	IDENT[PLACE]	DEPSEG
[tlŋgɪt]	*!		
☞ [təlŋgɪt]			*
[klŋgɪt]		*!	

2.3.2.5. ??[pw]

The phonological status of initial [pw] in American English has never been fully clarified. The [pw bw mw] onsets are often described as marginally acceptable by English-speaking linguists. Hultzén (1965) and Wooley (1970) consider [pw] a permissible English onset; Catford (1988) and Hammond (1999) consider it marginal, like the initial [ʒ] of *genre* or the initial [vɹ] of *vroom*.

> For /pw/ the example I have long used is puissant, attested for 1450 and occuring once per million words (1/M[17]) or within the first 20,000 words of

[16] The pronunciation [klŋkɪt] is deemed "correct" by the OED.
[17] Frequency counts in the quoted passage are from Thorndike & Lorge (1944).

> the language, but *pueblo* (1818) is more frequent (2/M including the place name) and is usually cited in whatever lists include this item. Both words are pronounced as indicated, although they do have alternative pronunciations not pertinent to our list. The word *bwana*, included by Hill and others, is rare, but /bw-/ is frequent in *Buenos Aires* (1/M) in both American English and RP (Hultzén 1965:12).

Wooley points out that low frequency cannot be the sole criterion of phonotactic badness:

> Initial /pw, bw, zw, mw/ pose a more difficult problem. As Hultzén has shown, *puissant*, dating from 1450, can hardly be rejected. To appeal to the low frequency of occurrence of these clusters in order to reject them would be to lose the natively English initial /ʧw/ as well (1970:74).

More modern frequency counts show that initial [θw] is more common than [pw] (Celex combined written and spoken, EFW.CD/EPW.CD: 6 per million vs. 1 per million; Francis-Kucera: 4 per million versus 0 per million), but the point is well taken. Hammond (1999) considers initial [pw] and [bw] to be of the same degree of marginality as [dw] (Celex has only *dwarf, dwell, dwindle,* and derivatives) and [θw] (Celex has only *thwack, thwart*).

If we assume that [pw bw mw] are actually illegal in English (that they are phonological rather than lexical gaps), then the illegality must be due to some active markedness constraint. It has been proposed by Clements & Keyser (1983) that English actively prohibits [labial][labial] sequences in the syllable onset. Again we have an effect of the Obligatory Contour Principle, forbidding adjacent identical segments in a particular domain (here, the syllable onset).

(2.44) OCP(LAB)
Adjacent labials are prohibited.

In order for this to be active, it must dominate some markedness constraint, so that an underlying [labial][labial] sequence is realized in some other way, repairing the violation. Already we can see that all is not well with this analysis: What is the repair? Jones (1997) gives faithful pronunciations for most word-initial [labial][labial] sequences, but some have alternate pronunciations in which the sequence is repaired:

(2.45) English pronunciations of [pw bw mw]-initial loans (Jones 1997).

pueblo	[puɛbloʊ]
puissant	[pjuːɪsənt]
Puerto (Rico)	[pɔːɹɾə]
poignant	[poɪɲənt]
Buenos (Aires)	[boʊnəs]
moiré	[mɔːɹeɪ]
Moivre	[moɪvəɹ]

The repairs are unsystematic and look suspiciously like spelling pronunciations – as if the disappearing [labial][labial] sequence were a victim of grapheme-to-phoneme conversion rules rather than synchronic phonological grammar.

Moreover, other [labial][labial] onset clusters are common in English. Since, as Delattre & Freeman (1968) found, [r] is [+round], the legal onset clusters [pr br fr] all violate OCP(LAB). Hence this constraint must be ranked too low to compel a repair.

Intuitive judgments of "wordlikeness" have been shown to be strongly influenced by differing frequency of the sequences contained in them, even when the sequences are phonotactically legal and attested (Coleman & Pierrehumbert 1997; Frisch et al. 2000). The intuitive-wordlikeness-judgment task will therefore be sensitive to lexical as well as phonological gaps. If [pw] is legal in English, but very rare, it may be judged unacceptable on the grounds of low phonotactic probability alone, even though [pw] words are possible. The onsets [tl] and [sɹ] will be judged worse, being both illegal and rare. This would account for the pattern of judgments and attestations reported in the phonological literature.

I will therefore analyze [pw] as a lexical rather than a phonological gap.

2.4. Summary

Optimality Theory views both inventory and phonotactics as consequences of the same grammar. Systematic, productive gaps in the inventory and in the set of phonotactically permissible combinations arise from the filtering effect of the grammar on the unconstrainted set of possible inputs. A productive, *phonological* gap in the set of observed surface forms is one which could not be the output of any conceivable input from the lexicon. A nonproductive, *lexical* gap is one which could be filled by some input from the lexicon, but where the necessary input (through historical accident) is not a lexical item.

Two highly productive gaps in the set of English syllable onsets were discussed: That on initial [sɹ], and that on initial [tl]. Both were shown to be special cases of systematic prohibitions involving neighboring coronals. These phenomena, assimilation and the Obligatory Contour Principle (OCP), drive similar processes in many non-English languages. The gaps in the English syllable inventory were analyzed as phonological gaps, resulting from the filtering action of the grammar.

A systematic gap, but of doubtful productivity, was also analyzed: The partial ban on initial [pw]. The systematicity demands an OCP constraint on neighboring labials; however, the lack of productivty suggests that this constraint is not ranked high enough to be active. The gap is threfore treated as lexical.