PART II

Syllable Theory

Overview of Part II

The typology of syllable structure systems has been the object of a successful research effort over the last century and is fairly well understood empirically.[50] Basic theoretical questions remain open or undecided, of course, depite (or because of) the body of modern work in the area. Here we aim to show that the fundamental typological generalizations receive principled explication through the notion of *Factorial Typology*. The idea is that Universal Grammar provides a set of violable constraints on syllable structure, and individual grammars fix the relative ranking of these constraints. The typology of possible languages is then given by the set of all possible rankings.

Because of the considerable complexity that inheres in this domain, it is appropriate to approach it via the strategies of Galilean science, sometimes referred to as *Rational Inquiry* in the linguistic literature. Our discussion will therefore proceed through three degrees of decreasing idealization. First, in §6, we examine a kind of C/V theory: the key simplifying assumption being that the terminal nodes (segments) are pre-sorted binarily as to their suitability for peak (V) and margin (C) positions (*cf.* McCarthy 1979, Clements & Keyser 1983). Further, we consider only syllables with at most *one* symbol C or V in any syllabic position. Under this restrictions, the basic structural constraints are introduced and the ranking-induced typology is explored. Then, still within CV theory, we examine the finer grain of interactions between the structural constraints and various methods of enforcing them upon recalcitrant inputs.

Next, in §7, we show how the theory allows a rich set of alternations in Lardil to be explicated strictly in terms of the interactions of constraints on prosodic structure. In §8, we extend the CV theory, taking up the more ambitious task of constructing syllables from segments classified into a multi-degree sonority scale. We show how simple assumptions in Universal Grammar explain a universal typology of inventories of onset, nucleus, and coda segments. A licensing asymmetry between onsets and codas is derived from the structural asymmetry in the basic theory: well-structured syllables *possess* onsets but *lack* codas. In the course of extracting these typological consequences, a number of general analytical techniques are developed.

[50] We do not pretend to cite this veritably oceanic body of work. The interested reader should refer to such works as Bell & Hooper 1978 and, say, the references in the references of Goldsmith 1990.

6. Syllable Structure Typology I: the CV Theory

6.1 The Jakobson Typology

It is well-known that every language admits consonant-initial syllables .CV~., and that some languages allow no others; that every language admits open syllables .~V. and that some admit only those. Jakobson puts it this way:

> "There are languages lacking syllables with initial vowels and/or syllables with final consonants, but there are no languages devoid of syllables with initial consonants or of syllables with final vowels." (Jakobson 1962:526: Clements & Keyser 1983:29.)

As noted in the fundamental work of Clements & Keyser 1983, whence the quotation was cadged, these observations yield exactly four possible inventories. With the notation Σ^{XYZ} to denote the language whose syllables fit the pattern XYZ, the Jakobson typology can be laid out as follows, in terms of whether onsets and codas are obligatory, forbidden, or neither:

(113) **CV Syllable Structure Typology**

		onsets	
		required	not required
codas	forbidden	Σ^{CV}	$\Sigma^{(C)V}$
	allowed	$\Sigma^{CV(C)}$	$\Sigma^{(C)V(C)}$

There are two independent dimensions of choice: whether onsets are required (first column) or not (second column); whether codas are forbidden (row one) or allowed (row two).

The **Basic Syllable Structure Constraints**, which generate this typology, divide notionally into two groups. First, the structural or 'markedness' constraints – those that enforce the universally unmarked characteristics of the structures involved:

(114) **Ons**
A syllable must have an onset.

(115) **−Cod**
A syllable must **not** have a coda.

Second, those that constrain the relation between output structure and input:

(116) **PARSE**
Underlying segments must be parsed into syllable structure.
(117) **FILL**
Syllable positions must be filled with underlying segments.

PARSE and FILL are Faithfulness constraints: they declare that perfectly well-formed syllable structures are those in which input segments are in one-to-one correspondence with syllable positions.[51] Given an interpretive phonetic component that omits unparsed material and supplies segmental values for empty nodes, the ultimate force of PARSE is to forbid deletion; of FILL, to forbid insertion.

It is relatively straightforward to show that the Factorial Typology on the Basic Syllable Structure Constraints produces just the Jakobson Typology. Suppose Faithfulness dominates *both* structural constraints. Then the primacy of respecting the input will be able to force violations of both ONS and −COD. The string /V/ will be parsed as an onsetless syllable, violating ONS; the string /CVC/ will be parsed as a closed syllable, violating −COD: this gives the language $\mathbf{\Sigma}^{(C)V(C)}$.

When a member of the Faithfulness family is dominated by one or the other or both of the structural constraints, a more aggressive parsing of the input will result. In those rankings where ONS dominates a Faithfulness constraint, every syllable must absolutely have an onset. Input /V/ cannot be given its faithful parse as an onsetless syllable; it can either remain completely unsyllabified, violating PARSE, or it can be parsed as .□V., where '□' refers to an empty structural position, violating FILL.

Those rankings in which −COD dominates a Faithfulness constraint correspond to languages in which codas are forbidden. The imperative to avoid codas must be honored, even at the cost of expanding upon the input (*FILL) or leaving part of it outside of prosodic structure (*PARSE).

In the next section, we will explore these observations in detail. The resulting Factorial construal of the Jakobson Typology looks like this (with '$\mathscr{F}$' denoting the Faithfulness set and 'F_i' a member of it):

[51] Both FILL and PARSE are representative of families of constraints that govern the proper treatment of child nodes and mother nodes, given the representational assumptions made here. As the basic syllable theory develops, FILL will be articulated into a pair of constraints:

FILL^{Nuc}: Nucleus positions must be filled with underlying segments.

FILL^{Mar}: Margin positions (Ons and Cod) must be filled with underlying segments.

Since unfilled codas are never optimal under syllable theory alone, shown below in §6.2.3 (141), p.104, FILL^{Mar} will often be replaced by FILL^{Ons} for perspicuity.

(118) **Factorial Jakobson Typology**

		Onsets	
		ONS ≫ F_j	$\mathscr{F}$ ≫ ONS
Codas	−COD ≫ F_i	$\sum^{CV}$	$\sum^{(C)V}$
	$\mathscr{F}$ ≫ −COD	$\sum^{CV(C)}$	$\sum^{(C)V(C)}$

At this point, it is reasonable to ask whether there is any interesting difference between our claim that constraints like ONS and −COD can be violated under domination and the more familiar claim that constraints can be *turned off* — simply omitted from consideration. The Factorial Jakobson Typology, as simple as it is, contains a clear case that highlights the distinction. Consider the language $\sum^{(C)V(C)}$. Since onsets are not required and codas are not forbidden, the Boolean temptation would be to hold that both ONS and −COD are merely absent. Even in such a language, however, one can find certain circumstances in which the force of the supposedly nonexistent structural constraints is felt. The string CVCV, for example, would always be parsed .CV.CV. and never .CVC.V. Yet both parses consist of licit syllables; both are entirely faithful to the input. The difference is that .CV.CV. satisfies ONS and −COD while .CVC.V. violates both of them. We are forced to conclude that (at least) one of them is still active in the language, even though roundly violated in many circumstances. This is the basic prediction of ranking theory: when all else is equal, a subordinate constraint can emerge decisively. In the end, summary global statements about *inventory*, like Jakobson's, emerge through the cumulative effects of the actual parsing of individual items.

6.2 The Faithfulness Interactions

Faithfulness involves more than one type of constraint. Ranking members of the Faithfulness family with respect to each other and with respect to the structural markedness constraints ONS and −COD yields a typology of the ways that languages can enforce (and fail to enforce) those constraints. We will consider only the Faithfulness constraints PARSE and FILL (the latter to be distinguished by sensitivity to Nucleus or Ons); these are the bare minimum required to obtain a contentful, usable theory, and we will accordingly abstract away from distinctions that they do not make, such as between deleting the first or second element of a cluster, or between forms involving metathesis, vocalization of consonants, de-vocalization of vowels, and so on, all of which involve further Faithfulness constraints, whose interactions with each other and with the markedness constraints will be entirely parallel to those discussed here.

6.2.1 Groundwork

To make clear the content of the Basic Syllable Structure Constraints ONS, −COD, PARSE, and FILL, it is useful to lay out the Galilean arena in which they play. The inputs we will be considering are

CV sequences like CVVCC; that is, any and all strings of the language {C,V}*. The grammar must be able to contend with any input from this set: we do not assume an additional component of language-particular input-defining conditions; the universal constraints and their ranking must do all the work (see §9.3 for further discussion).The possible structures which may be assigned to an input are all those which parse it into syllables; more precisely, into zero or more syllables. There is no insertion or deletion of *segments* C, V.

What is a syllable? To avoid irrelevant distractions, we adopt the simple analysis that the syllable node σ must have a daughter *Nuc* and *may* have as leftmost and rightmost daughters respectively the nodes *Ons* and *Cod*.[52] The nodes Ons, Nuc, and Cod, in turn, may each dominate C's and V's, or they may be empty. Each Ons, Nuc, or Cod node may dominate at most one terminal element C or V.

These assumptions delimit the set of candidate analyses. Here we list and name some of the more salient of the mentioned constraints. By our simplifying assumptions, they will stand at the top of the hierarchy and will be therefore unviolated in every system under discussion:

Syllable form:

(119) NUC

Syllables must have nuclei.

(120) *COMPLEX

No more than one C or V may associate to any syllable position node.[53]

Definition of C and V, using M(argin) for Ons and Cod and P(eak) for Nuc:

(121) *M/V

V may not associate to Margin nodes (Ons and Cod).

(122) *P/C

C may not associate to Peak (Nuc) nodes.

The theory we examine is this:

(123) **Basic CV Syllable Theory**

•Syllable structure is governed by the Basic Syllable Structure constraints

ONS, −COD, NUC; *COMPLEX, *M/V, *P/C; PARSE, and FILL.

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[52] For versions of the structural constraints within the perhaps more plausible moraic theory of syllable structure see Kirchner 1992bc, Hung 1992, Samek-Lodovici 1992, 1993, Zoll 1992, 1993, McCarthy & Prince 1993.

[53] On *complex* margins, see Bell 1971, a valuable typological study. Clements 1990 develops a promising quantitative theory of cross-linguistic margin-cluster generalizations in what can be seen as harmonic terms. The constraint *COMPLEX is intended as no more than a cover term for the interacting factors that determine the structure of syllable margins. For a demonstration of how a conceptually similar *complex* vs. *simple* distinction derives from constraint interaction, see §9.1-2 below.

- Of these, Ons, −Cod, Parse, and Fill may be relatively ranked in any domination order in a particular language, while the others are fixed in superordinate position.
- The Basic Syllable Structure Constraints, ranked in a language-particular hierarchy, will assign to each input its optimal structure, which is the output of the phonology.

The output of the phonology is subject to phonetic interpretation, about which we will here make two assumptions, following familiar proposals in the literature:

(124) **Underparsing Phonetically Realized as Deletion**
An input segment unassociated to a syllable position ('underparsing') is not phonetically realized.

This amounts to 'Stray Erasure' (McCarthy 1979, Steriade 1982, Itô 1986, 1989). Epenthesis is handled in the inverse fashion:

(125) **Overparsing Phonetically Realized as Epenthesis**
A syllable position node unassociated to an input segment ('overparsing') is phonetically realized through some process of filling in default featural values.

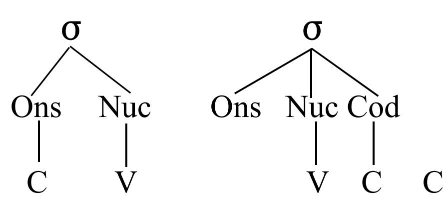
This is the treatment of epenthesis established in such works as Selkirk 1981, LaPointe & Feinstein 1982, Broselow 1982, Archangeli 1984, Kaye & Lowenstamm 1984, Piggott & Singh 1985, and Itô 1986, 1989.

The terms 'underparsing' and 'overparsing' are convenient for referring to parses that violate Faithfulness. If an input segment is not parsed in a given structure (not associated to any syllable position nodes), we will often describe this as 'underparsing' rather than 'deletion' to emphasize the character of our assumptions. For the same reason, if a structure contains an empty syllable structure node (one not associated to an input segment), we will usually speak of 'overparsing' the input rather than 'epenthesis'.

Suppose the phonology assigns to the input /CVVCC/ the following bisyllabic structure, which we write in three equivalent notations:

(126) **Transcription of Syllabic Constituency Relations**, from /CVVCC/

a.



b. $[_\sigma [_{Ons}\ C]\ [_{Nuc}\ V]]\quad [_\sigma [_{Ons}\ ]\ [_{Nuc}\ V]\ [_{Cod}\ C]]\ \ C$

c. .CV́.□V́C.⟨C⟩

Phonetic interpretation ignores the final C, and supplies featural structure for a consonant to fill the onset of the second syllable.

The dot notation (126c) is the most concise and readable; we will use it throughout. The interpretation is as follows:

(127) **Notation**

a. .X. ‘the string X *is a* syllable’
b. 〈x〉 ‘the element x has no parent node; is free (unparsed)’
c. □ ‘a node *Ons*, *Nuc*, or *Cod* is empty’
d. x́ ‘the element x is a Nuc’

In the CV theory, we will drop the redundant nucleus-marking accent on V́. Observe that this is a ‘notation’ in the most inert and de-ontologized sense of the term: a set of typographical conventions used to refer to well-defined formal objects. The objects of linguistic theory — syllables here — are not to be confused with the literal characters that depict them. Linguistic operations and assessments apply to structure, not to typography.

We will say a syllable ‘has an onset’ if, like both syllables in the example (126), it has an Ons node, whether or not that node is associated to an underlying C; similarly with nuclei and codas.

The technical content of the Basic Syllable Structure Constraints (114−117) above can now be specified. The constraint ONS (114) requires that a syllable node σ have as its leftmost child an Ons node; the presence of the Ons node satisfies ONS whether empty or filled. The constraint −COD (115) requires that syllable nodes have no Cod child; the presence of a Cod node violates −COD whether or not that node is filled. Equivalently, any syllable which does not contain an onset in this sense earns its structure a mark of violation *ONS; a syllable which does contain a coda earns the mark *−COD.

The PARSE constraint is met by structures in which all underlying segments are associated to syllable positions; *each* unassociated or free segment earns a mark *PARSE. This is the penalty for deletion. FILL provides the penalty for epenthesis: each unfilled syllable position node earns a mark *FILL, penalizing insertion. Together, PARSE and FILL urge that the assigned syllable structure be faithful to the input string, in the sense of a one-to-one correspondence between syllable positions and segments. This is Faithfulness in the basic theory.

6.2.2 Basic CV Syllable Theory

We now pursue the consequences of our assumptions. One important aspect of the Jakobson Typology (113) follows immediately:

(128) **THM. Universally Optimal Syllables**

No language may prohibit the syllable .CV. Thus, no language prohibits onsets or requires codas.

To see this, consider the input /CV/. The obvious analysis .CV. (i.e., $[_\sigma [_{Ons}\, \mathrm{C}] [_{Nuc}\, \mathrm{V}]]$) is *universally optimal* in that it violates *none* of the universal constraints of the Basic CV Syllable Theory (123). No alternative analysis, therefore, can be more harmonic. At worst, another analysis can be equally good, but inspection of the alternatives quickly rules out this possibility.

For example, the analysis .CV□. violates −Cod and Fill. The analysis .C□́.V. violates Ons in the second syllable and Fill in the first. And so on, through the infinite set of possible analyses– [.⟨C⟩V.], [.C□́.⟨V⟩.], [.□́.C □́.□V.], *etc. ad inf.* No matter what the ranking of constraints is, a form that violates even one of them can never be better than a form, like .CV., with no violations at all.

Because every language has /CV/ input, according to our assumption that every language has the same set of possible inputs, it follows that .CV. can never be prohibited under the Basic Theory.

6.2.2.1 Onsets

Our major goal is to explicate the interaction of the structural constraints Ons and −Cod with Faithfulness. We begin with onsets, studying the interaction of Ons with Parse and Fill, ignoring −Cod for the moment. The simplest interesting input is /V/. All analyses will contain violations; there are three possible one-mark analyses:

(129) /V/ →

a. .V. *i.e.,* $[_\sigma [_{Nuc}\, \mathrm{V}]]$
b. ⟨V⟩ *i.e.,* no syllable structure
c. .□V. *i.e.,* $[_\sigma [_{Ons}\,] [_{Nuc}\, \mathrm{V}]]$

Each of these alternatives violates exactly one of the Basic Syllable Structure Constraints (114−117).

(130) **Best Analyses of /V/**

Analysis	Interpretation	Violation	Remarks
.V.	σ lacks Ons	*Ons	satisfies Fill, Parse
⟨V⟩	null parse	*Parse	satisfies Ons, Fill
.□V.	Ons is empty	*Fill	satisfies Ons, Parse

Every language must evaluate all three analyses. Since the three candidates violate one constraint each, any comparison between them will involve weighing the importance of different violations. The optimal analysis for a given language is determined precisely by whichever of the constraints Ons, Parse, and Fill is *lowest* in the constraint hierarchy of that language. The lowest constraint incurs the least important violation.

Suppose .V. is the optimal parse of /V/. We have the following tableau:

(131) **Onset Not Required**

/V/	FILL	PARSE	ONS
☞ .V.			*
⟨V⟩		* !	
.□V.	* !		

The relative ranking of FILL and PARSE has no effect on the outcome. The violations of PARSE and FILL are fatal because the alternative candidate .V. satisfies both constraints.

Of interest here is the fact that the analysis .V. involves an onsetless syllable. When this analysis is optimal, then the language at hand, by this very fact, does not absolutely require onsets. The other two inferior analyses do succeed in satisfying ONS: ⟨V⟩ achieves this vacuously, creating no syllable at all; .□V. creates an onsetful syllable by positing an empty Ons node, leading to epenthesis. So if .V. is best, it is because ONS is the lowest of the three constraints, and we conclude that the language does not require onsets. We already know from the previous section, Thm. (128), that onsets can never be forbidden. This means the following condition holds:

(132) If PARSE, FILL $\gg$ ONS, then onsets are not required.

(The comma'd grouping indicates that PARSE and FILL each dominate ONS, but that there is no implication about their own relative ranking.)

On the other hand, if ONS is not the lowest ranking constraint, — if either PARSE or FILL is lowest — then the structure assigned to /V/ will be consistent with the language requiring onsets. The following two tableaux lay this out:

(133) **Enforcement by Overparsing (Epenthesis)**

/V/	ONS	PARSE	FILL
.V.	* !		
⟨V⟩		* !	
☞ .□V.			*

(134) **Enforcement by Underparsing (Deletion)**

/V/	FILL	ONS	PARSE
.V.		* !	
☞ ⟨V⟩			*
.□V.	* !		

These lucubrations lead to the converse of (132):

(135) If ONS dominates either PARSE or FILL, then onsets are required.

There is an important difference in status between the two ONS-related implications. To prove that something is *optional*, in the sense of 'not forbidden' or 'not required' in the inventory, one need merely exhibit one case in which it is observed and one in which it isn't. To prove that something is *required*, one most show that everything in the universe observes it. Thus, formal proof of (135) requires considering not just one trial input, as we have done, but the whole (infinite) class of strings on {C,V}* which we are taking to define the universal set of possible inputs for the Basic Theory. We postpone this exercise until the appendix; in §8 we will develop general techniques which will enable us to extend the above analysis to arbitrary strings, showing that what is true of /V/ and /CV/ is true of all inputs.

The results of this discussion can be summarized as follows:

(136) **Onset Theorem**.

Onsets are not required in a language if ONS is dominated by both PARSE and FILL. Otherwise, onsets are required.

In the latter case, ONS is enforced by underparsing (phonetic deletion) if PARSE is the lowest ranking of the three constraints; and by overparsing (phonetic epenthesis) if FILL is lowest.

If FILL is to be articulated into a family of node-specific constraints, then the version of FILL that is relevant here is FILL^{Ons}. With this in mind, the onset finding may be recorded as follows:

Lowest constraint	Onsets are …	Enforced by …
ONS	Not required	N/A
PARSE	Required	V 'Deletion'
FILL^{Ons}	Required	C 'Epenthesis'

6.2.2.2 Codas

The analysis of onsets has a direct parallel for codas. We consider the input /CVC/ this time; the initial CV provides an onset and nucleus to meet the ONS and NUC constraints, thereby avoiding any extraneous constraint violations. The final C induces the conflict between −COD, which prohibits the Cod node, and Faithfulness, which has the effect of requiring just such a node. As in the corresponding onset situation (130), the parses which violate only one of the basic syllable structure constraints are three in number:

(137) **Best Analyses of /CVC/**

Analysis	Interpretation	Violation	Remarks
.CVC.	σ has Cod	*−COD	satisfies FILL, PARSE
.CV⟨C⟩.	No parse of 2nd C	*PARSE	satisfies ONS, FILL
.CV.C□́.	2nd Nuc is empty	*FILL	satisfies ONS, PARSE

The optimal analysis of /CVC/ in a given language depends on which of the three constraints is lowest in the domination hierarchy. If .CVC. wins, then the language must allow codas; −COD ranks lowest and violation can be compelled. If .CVC. loses, the optimal analysis must involve open (codaless) syllables; in this case −COD is enforced through empty nuclear structure (phonetic V-epenthesis) if FILL is lowest, and through non-parsing (phonetic deletion of C) if PARSE is the lowest, most violable constraint. In either case, the result is that open syllables are *required*. This is a claim about the optimal parse in the language of every string, and not just about /CVC/, and formal proof is necessary; see the appendix.

The conclusion, parallel to (136), is this:

(138) **Coda Theorem**.

Codas are allowed in a language if −COD is dominated by both PARSE and FILL^{Nuc}.
Otherwise, codas are forbidden.

In the latter case, −COD is enforced by underparsing (phonetic deletion) if PARSE is the lowest ranking of the three constraints; and by overparsing (epenthesis) if FILL^{Nuc} is the lowest.

The result can be tabulated like this:

Lowest constraint	**Codas are …**	**Enforced by …**
−COD	Allowed	N/A
PARSE	Forbidden	C 'Deletion'
FILL^{Nuc}	Forbidden	V 'Epenthesis'

Motivation for distinguishing the constraints FILL^{Ons} and FILL^{Nuc} is now available. Consider the languages $\sum^{CV}$ in which only CV syllables are allowed. Here ONS and −COD each dominate a member of Faithfulness group. Enforcement of the dominant constraints will be required. Suppose there is only one FILL constraint, holding over all kinds of nodes. If FILL is the lowest-ranked of the three constraints, we have the following situation:

(139) **Triumph of Epenthesis**

Input	Optimal Analysis	Phonetic
/V/	.□V.	.ℂV.
/CVC/	.CV.C□́.	.CV.C𝕍.

The single uniform FILL constraint yokes together the methods of enforcing the onset requirement ('C-epenthesis') and the coda prohibition ('V-epenthesis'). There is no reason to believe that languages $\sum^{CV}$ are obligated to behave in this way; nothing that we know of in the linguistic literature suggests that the appearance of epenthetic onsets requires the appearance of epenthetic nuclei in other circumstances. This infelicitous yoking is avoided by the natural assumption that FILL takes individual node-classes as an argument, yielding FILL^{Nuc} and FILL^{Ons} as the actual constraints. In this way, the priority assigned to filling Ons nodes may be different from that for filling Nuc nodes.[54]

It is important to note that onset and coda distributions are completely independent in this theory. Any ranking of the onset-governing constraints {ONS, FILL^{Ons}, PARSE} may coexist with any ranking of coda-governing constraints {−COD, FILL^{Nuc}, PARSE}, because they have only one constraint, PARSE, in common. The universal factorial typology allows all nine combinations of the three onset patterns given in (136) and the three coda patterns in (138). The full typology of interactions is portrayed in the table below. We use subcripted *del* and *ep* to indicate the phonetic consequences of enforcement; when both are involved, the onset-relevant mode comes first.

[54] It would also be possible to break this yoke by having two separate PARSE constraints, one that applies to C and another to V. Basic syllable structure constraints that presuppose a C/V distinction, however, would not support the further development of the theory in §8, where the segment classes are derived from constraint interactions.

(140) **Extended CV Syllable Structure Typology**

			Onsets		
			required		not required
			ONS, FILL^{Ons} ≫ PARSE	ONS, PARSE ≫ FILL^{Ons}	PARSE, FILL^{Ons} ≫ ONS
Codas	forbidden	−COD, FILL^{Nuc} ≫ PARSE	$\sum^{CV}{}_{del,del}$	$\sum^{CV}{}_{ep,del}$	$\sum^{(C)V}{}_{del}$
		−COD, PARSE ≫ FILL^{Nuc}	$\sum^{CV}{}_{del,ep}$	$\sum^{CV}{}_{ep,ep}$	$\sum^{(C)V}{}_{ep}$
	allowed	PARSE, FILL^{Nuc} ≫ −COD	$\sum^{CV(C)}{}_{del}$	$\sum^{CV(C)}{}_{ep}$	$\sum^{(C)V(C)}$

If we decline to distinguish between the Faithfulness constraint rankings, this simplifies to the Jakobson Typology of (118).

6.2.3 The Theory of Epenthesis Sites

The chief goal of syllabification-driven theories of epenthesis is to provide a principled account of the location of epenthetic elements (Selkirk 1981, Broselow 1982, Lapointe and Feinstein 1982, Itô 1986, 1989). Theories based on manipulation of the segmental string are capable of little more than summary stipulation on this point (*e.g.* Levin 1985:331; see Itô 1986:159, 1989 for discussion). The theory developed here entails tight restrictions on the distribution of empty nodes in optimal syllabic parses, and therefore meets this goal. We confine attention to the premises of the Basic CV syllable structure theory, which serves as the foundation for investigation of the theory of epenthesis, which ultimately involves segmental and prosodic factors as well.

There are a few fundamental observations to make, from which a full positive characterization of syllabically-motivated epenthesis emerges straightaway.

(141) **Prop. 1**. $*[\ ]_{Cod}$

Coda nodes are never empty in any optimal parse.

Structures with unfilled Cod can never be optimal; there is always something better. To see this, take a candidate with an unfilled Cod and simply remove that one node. This gives another candidate which has one less violation of −COD and one less violation of FILL. Since removing the node has no other effects on the evaluation, the second candidate must be superior to the first. (To show that something is *non*-optimal, we need merely find something better: we don't have to display the best.)

We know from the earlier discussion that Ons and Nuc must be optimally unfilled in certain parses under certain grammars. So the remaining task is to determine the conditions under which these nodes must be posited and left empty.

(142) **Prop. 2**. *.(□)□́.
A whole syllable is never empty in any optimal parse.

The same style of argument applies. Consider a parse that has an entirely empty syllable. Remove that syllable. The alternative candidate thereby generated is superior to the original because it has (at least) one less FILL^{Nuc} violation and no new marks. The empty syllable parse can always be bested and is therefore never optimal.

Of course, in the larger scheme of things, whole syllables can be epenthesized, the canonical examples being Lardil and Axininca Campa (Hale 1973, Klokeid 1976, Itô 1986, Wilkinson 1988, Kirchner 1992a; Payne 1981, 1982, Spring 1990, Black 1991, McCarthy & Prince 1993). In all such cases, it is the impact of additional constraints that forces whole-syllable epenthesis. In particular, when the prosody/morphology interface constraints like LX≈PR are taken into account, prosodic minimality requirements can force syllabic epenthesis, as we will see for Lardil in §7 below.

(143) **Prop. 3**. *.(□)□́C.
No syllable can have *Cod* as its only filled position.

Any analysis containing such a syllable is bested by the alternative in which the content of this one syllable (namely 'C') is parsed instead as .C□́. . This alternative incurs only the single mark *FILL^{Nuc}, but the closed-syllable parse .(□)□́C. shares this mark and violates −COD as well. (In addition, the closed-syllable parse must also violate either ONS or FILL^{Ons}.)

Such epentheses are not unknown: think of Spanish /slavo/ → *e*slavo and Arabic /ħmarar/ → *ʔi*ħmarar. We must argue, as indeed must all syllable theorists, that other constraints are involved (for Arabic, see McCarthy & Prince 1990b).

(144) **Prop. 4**. *[ ][ ]
Adjacent empty nodes cannot occur in an optimal parse.

Propositions 1, 2 and 3 entail that [ ][ ] cannot occur inside a syllable. This leaves only the intersyllabic environment .C □́.□V~. This bisyllabic string incurs two marks, *FILL^{Nuc} and *FILL^{Ons}. Consider the alternative parse in which the substring /CV/ is analyzed as tautosyllabic .CV~. This eliminates both marks and incurs no others. It follows that two adjacent epentheses are impossible.

We now pull these results together into an omnibus characterization of where empty nodes can be found in optimal parses.

(145) **Fill Violation Thm. Location of possible Epenthesis Sites**.

Under the basic syllable structure constraints, epenthesis is limited to the following environments:

a) Onset, when Nucleus is filled:

.□V.

.□VC.

b) Nucleus, when Onset is filled:

.C □́.

.C □́C.

Furthermore, two adjacent epentheses are impossible, even across syllable boundaries.

We note that this result will carry through in the more complex theory developed below in §8, in which the primitive C/V distinction is replaced by a graded sonority-dependent scale.

7. Constraint Interaction in Lardil Phonology

The nominal paradigm of LARDIL, a Pama-Nyungan language of Australia,[55] displays a set of sometimes dramatic alternations that are responsive to constraints on syllable structure and word form. Detailed study and analysis of the language has established not only the facts of the matter, but also uncovered the essential structural factors that drive the phonology (Hale 1973; Klokeid 1976; Itô 1986; Wilkinson 1988; Kirchner 1992a). Of principal interest, from our point of view, is the coexistence of prosodically-governed augmentation and truncation patterns, competing for the same territory at the end of the word. Short stems are augmented; long stems can be truncated; and nothing happens to stems that are just the right size.

According to a current operational conception, the phonology would have rules of deletion and epenthesis that are blocked and triggered by various constraints: deletion of a final vowel *except when* the resulting output would be too short (blocking); addition of a vowel (or even consonant and vowel) *only when* the stem is not long enough (triggering); deletion of a final consonant sequence when unsyllabifiable (deletion triggered when syllabification is blocked). The major problem is to make sure that the right rule is controlled by the right constraint: although vowel-epenthesis is in the grammar, it is not used to save unsyllabified consonants; they delete. A second problem is keeping the rules at bay: excessive application of final V- and C-deletion (both in evidence) would result in very short words indeed.

It is important to see through such mechanical challenges to the fundamental insight behind the account: the role of prosodic output constraints in defining the system. Surely the key advance in the understanding of Lardil and similar systems was the introduction of analytical techniques that allowed many mutations of this sort to be rendered as consequences of syllabification and foot-formation, as in the work of Selkirk 1981, Broselow 1982, Steriade 1982, Itô 1986, 1989, McCarthy & Prince 1986, and for Lardil, Itô 1986 and Wilkinson 1988. The basic idea here is that the assignment of prosodic structure is *directly responsible* for a range of phenomena which early generative phonology attributed to a battery of structure-modifying re-write rules. Our program is to pursue this line of analysis with full vigor; we will argue that the major paradigmatic alternations in the Lardil noun are entirely consequent upon the prosodic parse.

7.1 The Constraints

We begin in this section by identifying the principal prosodic constraints operative in the language; in the next, we proceed to determine their relative ranking. The data are taken from Hale (1973), Klokeid (1976), Wilkinson (1988), and Kirchner (1992a). (After glosses we provide page number references, which are to Hale, except where otherwise noted.)

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[55] According to Hale, Lardil is "rather distantly related to the other Pama-Nyungan languages." The language is spoken on Mornington Island, one of the Wellesley group at the bottom of the Gulf of Carpentaria. Hale notes that it "is closely related to the other language spoken in the Wellesley group and adjacent mainland,… [which has] at least three dialects, Yanggal, Yukulta, Gayardilt." (Hale 1973: 421).

The phonological action we seek is found in the nominative case.[56] To make clear the character of the inflections we show some simple, alternation-free forms here:

(146) **Lardil Inflections**

	Stem	Nominative	Nonfuture Acc.	Future Acc.	Gloss	
a.	/kentapal/	kentapal	kentapal-in	kentapal-uţ	'dugong'	423
b.	/pirŋen/	pirŋen	pirŋen-in	pirŋen-uţ	'woman'	423

The nominative ending is null; the nonfuture accusative is *-in*; the future accusative is *-uţ*.

Most of Lardil syllable structure falls comfortably within the purview of the Basic Theory of §6. Lardil admits only syllables CV(C). Onsets are required, and underparsing is evidently used to enforce the ONS constraint when morphology puts V against V, as in the following example, showing the nonfuture accusative of /yukařpa/ 'husband':

(147) **Resolution of V+V**

Input	Phonological Analysis	Phonetic
/yukařp**a**+**i**n/	.yu.kař.pa⟨**i**⟩n.	yukařpan
	*.yu.kař.pa.□in.	*yukařpatin

(We will not be concerned with the details of the V+V phenomenon, however.) Lardil thus exemplifies the typological family $\sum^{CV(C)}{}_{del}$, in the terminology of the basic CV syllable structure theory of §6 (140). This means that the Faithfulness constraints dominate −COD, allowing codas when there is segmental motive for them in the input; and the constraint ONS dominates at least one of the Basic Theory's Faithfulness constraints, disallowing onsetless syllables.

Both Onsets and Codas are limited to a single segment, and nuclei consist of either a single short or long vowel. The relevant constraint from the basic theory is *COMPLEX (120), which says that syllable positions are limited to single segments. Long vowels, being monosegmental, satisfy this constraint. The constraint *COMPLEX is unviolated in Lardil, and will be seen to play an important role in the system.

For explicitness, we recall a few other characteristics of the basic theory. The constraint NUC (119) requiring syllables to have nuclei is assumed without comment to be undominated; similarly for the constraints *M/V (121) and *P/C (122) which prohibit vowels from being parsed as syllable

[56] There are a number of segmental and allomorphic alternations which will not be treated here, including the lowering of final vowels *u,i* →*a,e* and the process of sonorization t,ţ→ř,ţ/—#, of which the latter may be relevant to a later level of phonology than we discuss (see Hale 1973:426 fn. 32, Klokeid 1976 for details). These can be safely abstracted away from inasmuch as they do not interact with basic syllabification, which lies at the center of our concerns. For a different view of the system, the reader is referred to Kirchner 1992a, where the nominative form is analyzed not as uninflected but as bearing an abstract consonantal affix, one whose featural specification (though ill-formed at the surface) plays into the segmental alternations and which provides material for the cases that we regard as full syllable augmentation. In our formulations we note, but do not dwell on, Kirchner's conclusion that truncation is limited to nominals.

margins and consonants as being parsed as syllable peaks. These are unviolated in Lardil and therefore cannot be crucially subordinated. (A domination relation will be said to be 'crucial' if the output changes when it is reversed. When clear from context, 'crucial' will be omitted and, in particular, we will feel free to use 'undominated' to mean 'not crucially dominated'.) The division of segments in Lardil into vowels and consonants is uncomplicated: there is, evidently, no need to posit segments which alternate between peak and margin positions.

Looking beyond purely structural concerns, we find that codas in Lardil are subject to further strong limitations of the familiar kind (Steriade 1982, Itô 1986). Adopting Itô's term, we refer to the relevant constraint as the Coda Condition, CODACOND for short. The generalization offered by Wilkinson is that Codas may be occupied only by "nonback coronals" and by nasals homorganic with a following (onset) consonant. The consonant inventory of Lardil looks like this, with the 'nonback' coronals boxed:

(148) **Lardil Consonants** (Hale 1973)

	labial	lamino-dental	**apico-alveolar**	**lamino-alveolar**	**apico-domal**	dorso-velar
obstruent	p	t̪	t	t^y	ʈ	k
nasal	m	n̪	n	n^y	ɳ	ŋ
lateral			l			
flap			ř			
approximant	w			y	ɻ	

Caveat lector: the Lardil coronals referred to by Wilkinson as *back* are the farthest forward: the lamino-dentals [t̪ n̪]. The feature assignment is due to Stevens, Keyser, & Kawasaki 1986; evidently the lamino-dentals are velarized, so that that they have a Dorsal as well as a Coronal articulation. Excluded from syllable final position, then, is any consonant with a noncoronal specification (Labial or Dorsal), even secondarily. (On the unmarked status of coronals, see Paradis & Prunet 1991, McCarthy & Taub 1992). When a consonant has no place of its own, such as a linked nasal, it is of course also allowed in Coda position. Here we will do little more than summarize the effects of the condition, making no serious attempt to provide it or its variants with a proper analysis (for recent approaches, see Goldsmith 1990, Itô & Mester 1993, and within the present theory, Kirchner 1992bc, Zec 1992, and §8 and §9.1.2 below.)

(149) **CODACOND**

A coda consonant can have only Coronal place or place shared with another consonant.

The Coda Condition has serious consequences at the end of words, as can be seen in table (150) in the *Nominative* column.

(150) **Lardil Paradigms with Truncation**

Underlying Stem	•Nominative•	Nonfut. Acc.	Fut. Acc.	Gloss	
a. **C** Loss from Stem					
ŋalu**k**	ŋalu	ŋalu**k**-in	ŋalu**k**-uŗ	‘story’	438
wuŋkunu**ŋ**	wuŋkunu	wuŋkunu**ŋ**-in	wuŋkunu**ŋ**-kuŗ	‘queen-fish’	438
waŋal**k**	waŋal	waŋal**k**-in	waŋal**k**-uŗ	‘boomerang’	438
b. **V** Loss from Stem					
yiliyil**i**	yiliyil	yiliyil**i**-n	yiliyil**i**-wuŗ	‘oyster sp.’	424
mayař**a**	mayař	mayař**a**-n	mayař**a**-ŗ	‘rainbow’	424
c. **CV** Loss from Stem					
yukař**pa**	yukař	yukař**pa**-n	yukař**pa**-ŗ	‘husband’	424
wuţal**t^{y}i**	wuţal	wuţal**t^{y}i**-n	wuţal**t^{y}i**-wuŗ	‘meat’	424
ŋawuŋa**wu**	ŋawuŋa	ŋawuŋa**wu**-n	ŋawuŋa**wu**-ŗ	‘termite’	425
mukuni**ma**	mukuni	mukuni**ma**-n	mukini**ma**-ŗ	‘nullah’	425
d. **CCV** Loss from Stem					
muŋkumu**ŋku**	muŋkumu	muŋkumu**ŋku**-n	muŋkumu**ŋku**-ŗ	‘wooden axe’	425
t^{y}umput^{y}u**mpu**	t^{y}umput^{y}u	t^{y}umput^{y}u**mpu**-n	t^{y}umput^{y}u**mpu**-ŗ	‘dragonfly’	425

These underlying stems show up intact only when suffixed, here by the endings -in and -uŗ.[57] In the Nominative, with null affixation, a considerable amount of word-final material can be left behind. In the simplest case, a single consonant is lost, always one that cannot be syllabified because of the narrowness of the Coda Condition. Violations of CODACOND are avoided by failure to parse segments, as in the following typical example /ŋaluk/ ‘story, nom.’ (150a).

(151) **Enforcement of CODACOND** through underparsing

Stem	Parse	Phonetic
/ŋaluk/	.ŋa.lu.⟨k⟩	ŋalu
	*.ŋa.lu.k□́.	**ŋaluka*

Unparsed segments occur in Lardil, as in many other languages, in situations where violations of ONS and CODACOND are at risk. In addition, word-final vowels are generally left unparsed in the nominative. The stem /yiliyili/ is analyzed as *.yi.li.yil.⟨i⟩* when uninflected (150b). There are immediate further consequences: preceding consonants must also be left unparsed if syllabifying them would violate CODACOND. The resulting heavy losses are illustrated in (150c-d).

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[57] In addition to the V-loss mentioned above, the ending -uŗ undergoes various morphophonemic modifications of limited or unclear generality which will not be dealt with here. See Mester 1992 for discussion of allomorphy within an Optimality Theoretic conception of phonology.

Since nonparsing violates the prosodic licensing constraint PARSE, it will be avoided unless there is another, higher-ranked constraint that compels it. Wilkinson (1986:10) makes the interesting proposal that extrametricality is what's involved. Following this line, we formulate the relevant constraint so as to require that word-final vowels not be parsed (in the nominative).

(152) **FREE-V**

Word-final vowels must not be parsed (in the nominative).

Although FREE-V takes the bull by the horns, it would not perhaps be put forth as the canonical example of a universal markedness principle. It appears to be a morphologized reflex of the prosodic weakness of final open syllables, which are liable to de-stressing, de-voicing, shortening, truncation, and so on, under purely phonological conditions. (Estonian morphology has virtually the same constraint, including limitation to the nominative, the null-affixed case.) It also has connection with the commonly encountered constraint to the effect that stems or words must end in a consonant (McCarthy & Prince 1990ab, Prince 1990). Any theory must allow latitude for incursions of the idiosyncratic into grammar. What is important for our program is that such incursions are best expressible as *constraints*; that they are (slightly) modified versions of the universal conditions on phonological form out of which core grammar is constructed; and that they interact with other constraints in the manner prescribed by the general theory.

There is an important class of cases where, despite phonetic appearances, FREE-V is *not* violated. Since the constraint is phonological and pertains to phonological structure, it is vacuously satisfied in forms like *.ŋa.lu.⟨k⟩*, because the form *has no word-final vowel* in the relevant sense, its last vowel being separated from the word-edge by *k*. And the constraint is actively satisfied in *.muŋ.ku.mu.⟨ŋku⟩*, where the word-final vowel is unparsed, even though the phonetic interpretation *muŋ.ku.mu* ends, irrelevantly, in a syllabified vowel. Our analysis crucially rests, then, on the parallel satisfaction of constraints, as opposed to serial application of structure-deforming rules, and on the assumption of 'monotonicity' in the input/output relation — that the input is literally contained in the output, with no losses (cf. Wheeler 1981, 1988).

By contrast, the constraint FREE-V is flagrantly violated in bisyllabic stems, as illustrated in (153) by /wiţe/, which is parsed simply as *.wi.ţe.*

(153) **No Truncation in Minimal Words**

	Stem	Nominative	Nonfuture	Future	Gloss	
a.	wiţ**e**	wiţ**e**	wiţ**e**-n	wiţ**e**-ŗ	'inside'	W326
b.	mel**a**	mel**a**	mel**a**-n	mel**a**-ŗ	'sea'	433

Construing these as monosyllables to satisfy FREE-V would lead to violation of the strong universal prosody-morphology interface constraint discussed above in §4.3:

(154) **LX≈PR**

Every Lexical Word must correspond to a Prosodic Word.

Since the phonological category PrWd must dominate a foot, and since Lardil feet are binary by Foot Binarity (FTBIN, §4.3), adherence to LX≈PR entails bimoraic minimality. As shown in Wilkinson 1988, the resulting minimal word-size limitation correctly blocks stem-final vowel loss. The actual foot in Lardil may be the bimoraic trochee, with a syllable having one or two moras depending on whether its vowel is short or long, regardless of whether it has a coda. Details of foot form, of course, do not affect the minimality argument, since moraic binarity is the universal lower limit.

Not only does LX≈PR, in consort with FTBIN, prevent nonparsing of word-final vowels, it also forces the appearance of syllables with empty positions. The mono-moraic stems illustrated in (155) all receive syllabic augmentation in the nominative:[58]

(155) **Lardil Augmentation of Short Stems**

Underlying Stem	Nominative	Nonfuture	Future	Gloss	
a. **V** Augmentation					
yak	yak**a**	yak-in	yak-uŗ	'fish'	438
ŗelk	ŗelk**a**	ŗelk-in	ŗelk-uŗ	'head'	438
b. **CV** Augmentation					
maŗ	maŗ**ţa**	maŗ-in	maŗ-uŗ	'hand'	427
ŗil	ŗil**ta**	ŗil-in	ŗil-uŗ	'neck'	427
c. **CV** Augmentation					
kaŋ	kaŋ**ka**	kaŋ-in	kaŋ-kuŗ	'speech'	438
t^yaŋ	t^yaŋ**ka**	t^yaŋ-in	t^yaŋ-kuŗ	'some'	438

These stems cannot end underlyingly in the *-a* that shows up in the phonetics. The accusative markers are *-n* and *-ŗ* after true vowel-final stems, *-in* and *-uŗ* after consonant finals, as seen in (146) and (150) above. Nor can the underlying stems in (155b,c) be analyzed as ending in *-ta* or *-ka*, or even in *-t* and *-k*. Were the nominatives taken to reflect underlying consonantism, there would be no explanation for the putative disappearance of the additional consonants *t* and *k* in the oblique cases.

All subminimal stems are augmented. Not only are LX≈PR and FTBIN unviolated in the language, but the Null Parse output is inferior to the augmented forms, even though they violate FILL, which is therefore well down in the hierarchy.

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[58] In addition to the well-populated stem-shape categories exemplified in the table, there are two known CV stems: /ŗu/ 'body fat, grease', /t^ya/ 'foot'(Hale 1973:428, Klokeid 1976:55). These have the following forms: *ŗuwa, ŗuyin, ŗuuŗ; t^ya:, t^yayin, t^yawuŗ*. These are of interest for several reasons. Note the blocking of truncation of the affixal vowel, obviously due to the word minimality requirement; note also the use of a spreading structure rather than featural epenthesis to fill the Onset. The form *ŗuuŗ* (unattested: constructed from Klokeid's description) raises an issue about VV sequences; perhaps it is really *uwu*, with the *w* of low perceptibility in the *u—u* environment. The most serious problem for the analysis we give is the *t^ya:* nominative from /t^ya/. We point out the exact problem below, fn. 64, p. 130.

Augmentation violates FILL, but it does not always do so minimally, contrary to *ceteris paribus* expectation. Although a single empty position — a Nucleus — is sufficient to rescue excessively short stems CVC from Foot Binarity violations, the fact is that the accessory syllable may be entirely empty, with an unfilled Onset as well, as in *.maŗ.*□□́. and *.kaŋ.*□□́. (155b,c). Since all consonants of Lardil may stand in onset position, there is no phonological need for this extra FILL violation; the last consonant of the stem could easily fill the required Onset. Whence the supererogatory empty Onset? What's crucial, as Wilkinson points out (1986:7), is whether or not the stem-final consonant can be parsed as a Coda: when it can, it is.[59]

The generalization is clear in table (155). Supererogation is manifest in forms like (a), (b):

(156) **FILL Patterns** depending on syllabifiability of stem

Stem	Analysis	Phonetic
a. /maŗ/	.maŗ.□□́.	maŗţa
	*.ma.ŗ□́.	**maŗa*
b. /kaŋ/	.kaŋ.□□́.	kaŋka
	*.ka.ŋ□́.	**kaŋa*
c. /yak/	.ya.k□́.	yaka
	*.yak.□□́.	**yakta*

Where CODACOND can be met, as in (a) and (b), the stem-final consonant closes the stem syllable. Where it can't be met, as in (c), augmentation is minimal.[60] We propose that this pattern of generalization reflects another type of constraint on the morphology-phonology interface, one that requires edges of morphological constituents to match up with edges of phonological constituents.

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[59] Two patterns have been observed that indicate the need for refinement: /bit/→*bita*, **bitta*; and /teř/ →*teřa*, **teřta* (Hale 1973, Wilkinson 1988, Kirchner 1992a). In these cases, it appears that an onset [t] cannot be epenthesized because of constraints against geminate consonants and against the sequence [řt] (Hale 1973:427; recall the untreated alternation t~ ř, fn. 56, p.108. These constraints are sensitive to the phonetic content of the epenthetic onset, and not merely to its presence, yet they bear on syllabification, contrary to the hypothesis that epenthetic structure is nothing more than an empty syllabic node. For a further discussion of this phenomenon, see immediately below, fn. 60.

[60] The fact that the Coda Condition *is* met in forms like *.kaŋ.*□□́. (phonetic *kaŋka*) requires explication. Coda nasals must be homorganic to a following C; here there is no following C, only a syllabic position (under the current construal) lacking segmental content. This is a course a typical conundrum encountered in underspecification theories, in which the phonetic properties of the to-be-phonetically-filled-in material enter into the phonological constraint system of the language (Kiparsky 1968/73, Mohanan 1991, McCarthy & Taub 1992, McCarthy to appear). Such phenomena provide compelling evidence that the empty structure technology used here needs amplification: perhaps, for example, the set of candidates issued by Gen should include actual featural and segmental insertions, as well as new association lines. In such a theory, the cognate of FILL would militate against the presence of material not in the input, an obvious kind of unfaithfulness. We postpone consideration of such refinements for future research (see Yip 1993 for some suggestions). For present purposes, let us imagine that a syllable node bears the index of the segments associated with it (Aoun 1979), specifically of the *place* node of that segment, its head (Itô & Mester 1993); assume also that empty nodes can be introduced with indices. A form like *.kaŋ*$_i$.□$_i$□́. is regarded as legitimate by CODACOND because the nasal is indexed to a non-coda node. It appears that in Lardil only sonorants may be coindexed in this way. The phonetic interpretation process that fills in values for empty nodes would derive place information from coindexation. For deeper exploration of CODACOND-type issues, see Goldsmith 1990, Kaye 1990, Itô & Mester 1993 and the references cited therein.

In the examples of (156), we see that the end of the stem is made to coincide with a syllable edge, if that state of affairs can be achieved by epenthesis while still deferring to the general syllable structure restrictions of the language.

Although the phonological integrity of the stem is protected in forms like *maŗ.□a* , no such effect is observed internally at stem+affix junctures. We do not find, for example, *maŗ.□in* from /maŗ+in/ or *ken.ta.pal.□in* from /kentapal+in/. The morphological category at issue can therefore be determined quite precisely: the phenomenon involves only the final edge of the entire underlying collocation of stem+affixes. Let us call this entity the 'Morphological Word', or MWord. We may then state the relevant constraint:

(157) **ALIGN**

The final edge of a Morphological Word corresponds to the final edge of a syllable.

ALIGN belongs to the family of constraints which govern the relation between prosody and grammatical structure. Considerable further development and investigation of the ALIGN idea is found in McCarthy & Prince 1993a, which posits a general format for alignment constraints: ALIGN(GCat-edge(L|R), PCat-edge(L|R)), where GCat denotes a morphological or syntactic category; PCat denotes a prosodic category; L,R denote 'left' and 'right'. McCarthy & Prince demonstrate the central role of such constraints in a wide range of prosodic-morphological phenomena and explore the variety of effects that can be obtained by using them. Of particular interest in the present context is their finding that Axininca Campa right-aligns the Stem itself and not the MWord. (McCarthy & Prince (1993b) show that the Alignment family is instrumental in much prosodic phonology as well, incorporating and generalizing the EDGEMOST constraints posited above.) The ALIGN pattern is closely analogous to that proposed for the domain of phrasal phonology by Chen 1987 and further explored in Selkirk 1986, 1993. Observe that LX≈PR really falls into the same family: a lexical word edge is to be aligned with the edge of a Prosodic Word.
In the case at hand, the constraint ALIGN is violated unless the MWord's final segment stands as the final segment in a syllable. A consonant-final MWord satisfies ALIGN only if its final C is a Coda. A vowel-final MWord satisfies ALIGN only if its final V is parsed as the Nucleus of an open syllable. MWords in which the final segment is not parsed at all will violate ALIGN because the morphological-category edge does not fall at a syllable edge.

Like Axininca Campa, Lardil evidences both left and right morphology/prosody alignment. Truncation and Augmentation lead to frequent violations of final ALIGN (157), which looks at the end of the domain. By contrast, ALIGN-L, aimed at the leading edge of the Stem or MWord, is never violated: prosodic structure begins crisply at the beginning of the word, and empty structure never appears there. Word minimality considerations alone are insufficient to determine the placement of empty material, and languages differ on its location. Shona, Mohawk, and Choctaw, to cite three genetically separated examples, all use prothetic vowels to attain minimality (Myers 1987a, Hewitt 1992; Michelson, 1988; Lombardi & McCarthy 1991). In Lardil, as in Axininca Campa, augmentation is always final, being ruled out initially by ALIGN-L (McCarthy & Prince 1993:§4). Note that if LX≈PR actually works along Chen-Selkirk lines, as suggested above, then we can identify ALIGN-L with LX≈PR. The constraint would be that the initial edge of the lexical word must align with the initial edge of the prosodic word. Let's tentatively assume this formulation, and speak no more of ALIGN-L.

We have now surveyed the principal constraints involved in the alternations. The following list summarizes and categorizes the constraint set:

(158) **Principal Lardil Constraints** (not yet ranked)

a Basic Syllable Structure

ONS, −COD, FILL^{Ons}, FILL^{Nuc}, PARSE, *COMPLEX

b Segmental Association

CODACOND

c Foot Structure

FTBIN

d Morphology-Phonology Interface

LX≈PR, ALIGN, FREE-V

Of these constraints, only FREE-V involves a significant degree of language-particular idiosyncrasy. The others are strictly universal; and some, like ALIGN (i.e. ALIGN-R) and LX≈PR (qua ALIGN-L) point to the existence of a universal family of constraints whose other members are presumably available but subordinated out of sight in Lardil.

For the reader's convenience, the table on the following page lays out the the alternation system that the constraint set, when ranked, will generate.

Inputs are distinguished first according to whether they are consonant- or vowel-final, and then according to whether they are sub-minimal (one mora), minimal (two moras) or supra-minimal (more than two moras). On stems CV, see fn. 58, p. 112 above.

The table uses the following code:

T	pure coronal, a *possible* coda
$\mathbb{K}$	C with dorsal or labial articulation, *impossible* coda
$\mathbb{M}$	a nasal not pure coronal (a *possible coda only when* followed by a homorganic onset)
$\mathbb{Q}$	C that is an *impossible coda* for any reason. $\{\mathbb{Q}\} = \{\mathbb{M}\} \cup \{\mathbb{K}\}$
X^+	sequence of one or more elements of type X

(159) **Summary of Lardil Nominative Forms**

Consonant-Final Stems

Stem ≥ μμ				
a.	~T → ~T.	kentapa**l**	→	.ken.ta.pa**l**.
b.	$\sim\mathbb{Q}^+ \rightarrow \sim.\langle\mathbb{Q}^+\rangle$	waŋal**k**	→	.wa.ŋal.⟨**k**⟩
		ŋalu**k**	→	.ŋa.lu.⟨**k**⟩
Stem < μμ				
c.	~T → ~T.□□́.	ma**ţ**	→	.ma**ţ**.□□́.
d.	$\sim\mathbb{K} \rightarrow \sim.\mathbb{K}$□́.	ţel**k**	→	.ţel.**k**□́.
		ya**k**	→	.ya.**k**□́.
e.	$\sim\mathbb{M} \rightarrow \sim\mathbb{M}$.□□́.	ka**ŋ**	→	.ka**ŋ**.□□́.

Vowel-Final Stems

Stem > μμ				
f.	~TV → ~T.⟨V⟩	yiliyil**i**	→	.yi.li.yil.⟨**i**⟩
g.	$\sim\mathbb{Q}^+V \rightarrow \sim.\langle\mathbb{Q}^+V\rangle$	yukařpa	→	.yu.kař.⟨**pa**⟩
		ŋawuŋa**wu**	→	.ŋa.wu.ŋa.⟨**wu**⟩
		muŋkumu**ŋku**	→	.muŋ.ku.mu.⟨**ŋku**⟩
Stem = μμ				
h.	~V → ~V.	wiţ**e**	→	.wi.ţ**e**.

7.2 The Ranking

To construct a grammar of Lardil from the assembled constraints, it is necessary to fix their ranking. Our basic analytical strategy will be to examine competitions between pairs of candidates, one of which is desired to be optimal, the other of which provides a serious challenge, because it is favored by some constraint or constraints (§7.2.2). Each such competition will turn out to bear on the ranking relations between a small number of conflicting constraints. The end result will be a collection of ranking conditions, which must hold of any grammar that is successful in generating the desired forms. These conditions are combined into an overall ranking (more precisely: class of rankings) for the whole set of constraints.

We then go on to show in §7.3 that the posited rankings are not only necessary, but sufficient to produce the desired outputs: that a grammar of constraints so ranked will dismiss not just the small set of losing competitors considered in §7.2.2, but will indeed dismiss *every* nonattested output candidate as suboptimal.

Before we plunge into this task, we offer two remarks on the logic of constraint-ranking arguments. The first is fundamental to the project of advancing from empirical observations to sound conclusions about necessary rankings. The second offers a refinement useful for deducing rankings under the particular conditions comprehended by Pāṇini's Theorem (§5.3).

7.2.1 Some Ranking Logic

There are risks involved in focussing on only two constraints in a situation where a number of constraints are swarming about, their interactions unresolved. When is it safe to conclude that an argument about two constraints can't be invalidated by the introduction of a third into the discussion? Fortunately, the issue submits to a simple resolution.

Consider the basic situation in which two constraints, call them $\mathbb{C}_1$ and $\mathbb{C}_2$, are directly rankable. For a ranking argument to exist at all, the constraints must *conflict*. This means that they disagree on the the relative Harmony of competing candidate forms arising from a given input, where one of the candidates is the true output. Let's denote the forms on which $\mathbb{C}_1$ and $\mathbb{C}_2$ conflict by the names ω and z. Suppose ω is the empirically correct output, which must be optimal under the constraint hierarchy, if the grammar is to be successful. Suppose further that $\mathbb{C}_1$ favors ω over z, but that the conflicting $\mathbb{C}_2$ favors z over ω.

In this situation, it is clear that $\mathbb{C}_2$ must be subordinated in the ranking to *some* constraint favoring ω over z — otherwise ω will not win against z. If the choice between ω and z is relevant to the ranking of $\mathbb{C}_1$ and $\mathbb{C}_2$, then the constraint that grants relative superiority to ω — here, $\mathbb{C}_1$ — must be dominant. A typical conflict situation is shown in the following tableau.

(160) **Constraint Conflict and Ranking Argument**

Candidates from /input$_i$/		$\mathbb{C}_1$	$\mathbb{C}_2$
☞	ω		*
	z	* !	

This constitutes a *potential* empirical argument that $\mathbb{C}_1$ dominates $\mathbb{C}_2$. Are we then licensed to conclude that the domination relation $\mathbb{C}_1 \gg \mathbb{C}_2$ must be honored by the grammar under investigation? Could it be that another constraint in the grammar — call it $\mathbb{D}$ — is actually responsible for the victory of ω over *z*, mooting the clash of $\mathbb{C}_1$ and $\mathbb{C}_2$?

Indeed it could, but any such spoiler constraint must meet tight conditions. First of all, ω and *z* cannot tie on $\mathbb{D}$; for if they do, $\mathbb{D}$ plays no role in deciding between them. Second, $\mathbb{D}$ cannot favor *z* over ω: no such constraint, disfavoring ω, can be responsible for its triumph over a competitor.

This leaves only the situation where $\mathbb{D}$ favors ω over z, exactly as $\mathbb{C}_1$ does. Such constraints have the power to decide the competition in favor of ω. These are the ones to watch out for. If there are none, or if they have already been shown to be lower-ranked than $\mathbb{C}_2$ by other considerations, then the ranking argument in (160) goes through and establishes a necessary condition on the grammar.[61] (Should such a potential rejector exist, and should we have no reason to believe that it must be ranked below $\mathbb{C}_2$, we can only conclude that $\mathbb{C}_1$ *or* $\mathbb{D}$ is ranked above $\mathbb{C}_2$.)

To put it another way: a successful direct ranking argument shows that $\mathbb{C}_1$ is the *rejector* of the candidate *z* in its contest against ω, *i.e.* that $\mathbb{C}_1$ is the very constraint that puts an end to *z*'s candidacy. The only type of constraint whose presence in the grammar would undermine the argument is another potential rejector of *z vis-à-vis* ω.

As a second point of useful ranking logic, we review the discussion of Pāṇini's Theorem on Constraint-ranking from §5.3. Intuitively, this theorem says that if a more general and a more specific constraint disagree, then they can only both be active in winnowing the candidate set of an input if the specific constraint dominates the general one. The first relevant case of this theorem in Lardil involves the more general constraint PARSE and the more specific constraint FREE-V which disagrees with the more general one on its more specialized domain, V-final stems.

Let us review the relevant definitions from §5.

[61] This argument can be re-phrased in terms of the Cancellation/Domination Lemma below: §8.2.6, (192), p.142,and (238), p.162. The Cancellation/Domination Lemma holds that each mark incurred by the overall winner ω must be canceled or dominated by the marks of any competitor. Let us suppose, without loss of generality, that we are looking at fully canceled tableaux, in which all common marks have been eliminated. The form ω has a mark *$\mathbb{C}_2$; the claim of the comparison in tableau (160) is that $\mathbb{C}_1$ crucially supplies the dominating mark for *z*. Of course, there might be another constraint around, $\mathbb{D}$, which actually supplies the dominating mark. To fill this role, $\mathbb{D}$ would have to give a mark to *z* and no mark to ω, just like $\mathbb{C}_1$.

(161) Dfn. **Pāṇinian Constraint Relation**

Let $\mathbb{S}$ and $\mathbb{G}$ be two constraints. $\mathbb{S}$ *stands to* $\mathbb{G}$ *as special to general in a Pāṇinian relation* if, for any input i to which $\mathbb{S}$ applies non-vacuously, any parse of i which satisfies $\mathbb{S}$ fails $\mathbb{G}$.

A constraint applies *non-vacuously* to an input i if some of the parses of i violate the constraint while others satisfy it.

For example, the constraint FREE-V stands to PARSE as special to general in a Pāṇinian relation. Given any input to which FREE-V applies non-vacuously — an input with a stem-final vowel V — any parse of it which satisfies FREE-V by leaving V unparsed must for that very reason violate PARSE.

The other concept we need is:

(162) Dfn. **Active**

Let $\mathbb{C}$ be a constraint in a constraint hierarchy $\mathbb{CH}$ and let i be an input. $\mathbb{C}$ is *active on* i *in* $\mathbb{CH}$ if $\mathbb{C}$ eliminates from consideration some candidate parses of i.

That is, among those candidate parses of i which survive the constraints which dominate $\mathbb{C}$ in the hierarchy $\mathbb{CH}$, some violate $\mathbb{C}$ and others satisfy it, so $\mathbb{C}$ eliminates those parses which violate it. (Recall that in harmonic ordering, if all the candidates left for consideration by $\mathbb{C}$ violate $\mathbb{C}$, then $\mathbb{C}$ does not eliminate any of these parses.)

Now the theorem asserts:

(163) **Pāṇini's Theorem on Constraint-ranking** (PTC)

Let $\mathbb{S}$ and $\mathbb{G}$ stand as specific to general in a Pāṇinian constraint relation. Suppose these constraints are part of a constraint hierarchy $\mathbb{CH}$, and that $\mathbb{G}$ is active in $\mathbb{CH}$ on some input i. Then if $\mathbb{G} \gg \mathbb{S}$, $\mathbb{S}$ is not active on i.

Thus if both the general and specific constraints are active on a common input, the specific must dominate the general. We will see shortly how PTC can be used to help deduce the domination hierarchy of Lardil. For other examples of PTC and related patterns of argument, see Kirchner 1992bc and McCarthy & Prince 1993.

PTC has obvious affinities with the Elsewhere Condition of Anderson 1969 and Kiparsky 1973b, which has played an important role in enriching and deepening the theory of Lexical Phonology. There is an important difference: PTC is merely a point of logic, but the Elsewhere Condition is thought of as a principle specific to UG, responsible for empirical results which could very well be otherwise. In Kiparsky 1973b, for example, the Elsewhere Condition is written to govern the relationship between rules whose structural changes are *the same* as well as incompatible (broadly, 'conflicting'). This enables him to claim that it is the Elsewhere Condition, rather than the interpretation of parentheses, that is responsible for disjunctive ordering in stress rules. Suppose a grammar has the two (adjacent) rules 'stress the penult' and 'stress the final syllable'. Since every word has a final syllable, but not every word a penult, it follows from the Elsewhere Condition that in longer words *only* the penult stress rule applies. It is logically possible that both rules would apply, stressing the last two syllables in longer words. Current prosodic theory yields a better understanding of the phenomenon. In reality, the two stress rules are incompatible: conflicting, not identical in structural change. If main stress is at issue, then the relevant constraints entail that there can be only one such in word. (Each rule then says "*the* main-stress is here.") The ranking decides which position is favored; and either is possible. If mere stress vs. unstress is at issue, then Foot Binarity decides the matter (not to mention anti-clash constraints).

Along the same lines, the Elsewhere Condition is sometimes said to entail that a given morphological category should have only one marking; double marking of *e.g.* plural by two different affixes, one specialized, the other of more general applicability, is then held to be an "exception" to the Elsewhere Condition (Stump 1989). Here again, it should be clear that what's really at issue is a substantive matter: how morphological categories are expressed. A morphosyntactic feature [+PL] typically has one morpheme in a string devoted to it (Pinker 1984, Marcus et al. 1992); thus, different plural morphemes are *incompatible*. This allows for a special-case/general-case system, in which the logic of PTC determines the ranking that yields the observed facts. What double marking challenges is the assumption of incompatibility, without which the PTC is irrelevant. We conclude that the standard Elsewhere Condition folds together a point of logic (PTC) with additional claims about what linguistic phenomena are incompatible. With the incompatibility claims properly factored out into substantive constraints of various types, what's left is PTC; that is to say, nothing.

7.2.2 Ranking the Constraints

Let us now turn to the business at hand. We repeat the constraint list for convenience of reference.

(164) **Principal Lardil Constraints** (not yet ranked)

a. Basic Syllable Structure

ONS, −COD, FILL^{Ons}, FILL^{Nuc}, PARSE, *COMPLEX

b Segmental Association

CODACOND

c Foot Structure

FTBIN

d Morphology-Phonology Interface Constraints

LX≈PR, ALIGN, FREE-V

Five of the constraints are never violated in Lardil, and are therefore not crucially dominated. In any given grammar, which is imposes a total order on the constraint set, all but one will be formally dominated; but permuting the ranking relations among the members of this set will have no effect on the outcome.

(165) **Constraints Not Crucially Dominated**

ONS, CODACOND,*COMPLEX, LX≈PR, FTBIN

It remains to be determined how each of these top-rankable constraints is *enforced* via domination of a relevant faithfulness constraint. We will find direct evidence in the cases of ONS, LX≈PR, FTBIN. Note that the constraint *COMPLEX, which bans tautosyllabic sequences, is undominated in Lardil just as it is in the basic syllable structure theory of §6 (123), p. 96.

Lardil is a member of the family $\sum^{CV(C)}{}_{del}$ of CV(C) languages (§6.1), with mandatory onset enforced by omitting stranded V's, as in VV, from syllable structure. From the discussion in §6, we know how to define this family:

(166) **Mandatory Onset Enforced by Failure to Parse**

ONS, FILL^{Ons} ≫ PARSE

Input sequences CVV are resolved as .CV.〈V〉, incurring a *PARSE violation, as seen in the postvocalic disappearance of *-i* in *-in* 'nonfuture accusative'. The alternatives which posit an Onsetless syllable .V., or an empty Onset position as in .□V., are declared less harmonic by this ranking. (Since we are not treating the resolution of VV in any depth here, we abstract away from the issue of deciding which V of VV is to remain unparsed, and we will therefore not offer a constraint discriminating C〈V〉V from CV〈V〉.)

(167) **Coda Allowed**

FILL^{Nuc}, PARSE ≫ −COD

Syllables can have codas. Input CVCCV, for example, is syllabified faithfully (CodaCond willing), rather than submitted to aggressive over- or under-parsing that would support the preconsonantal C with an empty nucleus (*FILL^{Nuc}) or eject it altogether from syllable structure (*PARSE).

Let us consider now the position of the pair LX≈PR and FTBIN, which jointly entail the minimality limitation on words. These two are clearly undominated, because never violated. In addition, they must be specifically ranked above certain other constraints. Operationally speaking, the minimal word size condition must *trigger* epenthesis and *block* deletion. In Optimality Theoretic terms, a constraint that is said to trigger or to block is simply dominant; there are no distinguished triggering and blocking relations. Consequently LX≈PR and FTBIN must be dominant over the FILL constraints, which militate against empty structure (*triggering* its appearance), and over the FREE-V constraint, which favors nonparsing of word-final V (*blocking* the nonparse).

To see the details, let's first examine the augmentation of subminimal stems. The constraints LX≈PR and FTBIN are enforced by positing empty syllabic nodes, sometimes unfilled Onset as well as unfilled Nucleus. It follows that:

(168) **LX≈PR, FTBIN Enforced via Empty Structure**

LX≈PR, FTBIN ≫ FILL^{Nuc}, FILL^{Ons}

Parses such as *.maȷ.*□□́. are therefore optimal, despite violation of both FILL^{Ons} and FILL^{Nuc}. In any candidate without the additional syllable, fatal violation of the higher-ranked constraints LX≈PR or FTBIN must occur. The tableau below shows only the LX≈PR violation, caused by failure to foot the input. Assigning the input a monomoraic foot would make it possible to satisfy LX≈PR, but at the unacceptable cost of violating FTBIN.

/maţ/	LX≈PR	FILL^{Nuc}	FILL^{Ons}
☞ [($_F$ .maţ.□□́.)]$_{PrWd}$		*	*
.maţ.	* !		

Notice that we are justified in ignoring the other constraints here. *Both* candidates fail −COD; both satisfy ALIGN; so neither constraint can decide between them.

In forms that are precisely minimal, stem-final vowels are parsed in violation of FREE-V, because of the domination of LX≈PR and FTBIN.

(169) **LX≈PR, FTBIN Force Parsing of Stem-Final Vowels**
LX≈PR, FTBIN ≫ FREE-V

In vowel-final bimoraic stems CVCV, FREE-V conflicts with LX≈PR and FTBIN. Parsing the final vowel violates FREE-V. Leaving it out produces a monosyllabic monomoraic output, violating either LX≈PR or FTBIN. The conflict goes to LX≈PR and FTBIN, of course. The following tableau shows the LX≈PR situation, considering candidates in which no monomoraic feet are assigned:

(170) **Failure of Truncation in Minimal Words**

/wiţe/ →	LX≈PR	FREE-V
☞ [(.wi.ţe.)]$_{PrWd}$		*
.wiţ.⟨e⟩	* !	

The constraint FREE-V also interacts with PARSE, but in the simple way covered by Pāṇini's Theorem. As mentioned in §7.2.1, FREE-V stands to PARSE as specific to general in a Pāṇinian relation: on those inputs where FREE-V applies non-vacuously, V-final stems, satisfying FREE-V entails violating PARSE.

In fact, FREE-V also stands to ALIGN as specific to general in the Pāṇinian relation: in V-final stems, satisfying FREE-V entails that the right MWord boundary (after V) is not a syllable boundary. Now let $\mathbb{G}_1$ denote whichever of the general constraints PARSE and ALIGN is higher-ranked in Lardil, and $\mathbb{G}_2$ the other. Consider the possibility that the special constraint $\mathbb{S}$ = FREE-V is dominated by $\mathbb{G}_1$. Then $\mathbb{G}_1$ must be active on supraminimal V-final stems, eliminating parses like .CV.CV.CVT.⟨V⟩, where T symbolizes a legal coda as in *yi.li.yil.*⟨*i*⟩, which violate no other constraints except $\mathbb{G}_2$, which is lower-ranked than $\mathbb{G}_1$. So by PTC, since the general constraint $\mathbb{G}_1$ is active on V-final stems, the special constraint $\mathbb{S}$ = FREE-V cannot be active on these inputs: in other words, it may as well not be in the grammar, since it cannot do the work we require of it. Thus this possibility is ruled out: $\mathbb{S}$

must dominate $\mathbb{G}_1$. Since by definition $\mathbb{G}_1$ is the more dominant of PARSE and ALIGN, it follows that FREE-V must dominate *both* PARSE and ALIGN:

(171) **Pāņini's Theorem (w.r.t. Final Vowel Parsing)**, Case 1
FREE-V ≫ PARSE

(172) **Pāņini's Theorem (w.r.t. Final Vowel Parsing)**, Case 2
FREE-V ≫ ALIGN

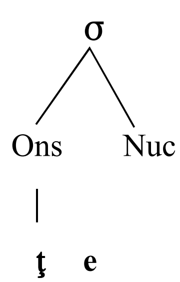
Those who are skeptical of the power of pure reason may wish to examine the following tableau to see the Pāņinian conclusion affirmed.

(173) **Pāņini Vindicatus**

/yiliyili/	FREE-V	ALIGN	PARSE
☞ .yi.li.yil.⟨i⟩		*	*
.yi.li.yi.li.	* !		

A less obvious interaction between FREE-V and FILL^{Nuc} is implicated here as well. It is actually possible to omit the final vowel in /wiţe/ from syllable structure while keeping the overall output bisyllabic: implant an empty final nucleus to replace, as it were, the unparsed vowel. The end-of-the-word structure would look like this:

(174) Simultaneous Under- and Over-parsing /wiţe/ → **wiţa*



This analysis can be transcribed as *.wi.ţ*□́.⟨*e*⟩ if we keep in mind that no linear order holds between □́ = Nuc and the segment ⟨*e*⟩, as is apparent in the fuller diagram (174). The simultaneous truncation/augmentation analysis is plausible because both structures occur independently with other stems; why should they not be superimposed? That this devious analysis is not correct implies that the violation of FILL^{Nuc} by *.wi.ţ*□́.⟨*e*⟩ is worse than the violation of FREE-V incurred by *.wi.ţe*. We must have FILL^{Nuc} dominating FREE-V, with results as shown in the following tableau:

(175) **No Truncation and Augmentation of the same Stem**

/wiţe/	FILL^{Nuc}	FREE-V
.wi.ţe.		*
.wi.ţ □́.⟨e⟩	* !	

The required ranking is recorded here:

(176) **Unparsed Stem-Final Vowels not Replaced with Empty Nuc**
FILL^{Nuc} ≫ FREE-V

This ranking asserts that FREE-V will be sacrificed to avoid epenthesis.[62]

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[62] A more interesting line of attack on this problem is potentially available within the present theory. Suppose that the constraint responsible for the truncation pattern is not, like FREE-V, in the mold of Bottom Up Constructionism (of which extrametricality is a necessary adjunct), but pertains instead to the syllable structure, and, top-down, bans open syllables from final position. Such a constraint is recognizable as a specialization of the NONFINALITY family of §4.3. Instead of demanding that the head of a PrWd or the head of a Foot not stand in final position, this constraint demands that the head of a *syllable* not be final. Call this constraint *NONFINSYLHD*. Forms like *.ŋa.lu.⟨k⟩* and *.muŋ.ku.mu.⟨ŋku⟩* satisfy the constraint because no syllable head is truly final, the head of the *last* syllable being separated from the word-edge by unparsed segmental material. Crucially, augmentation also violates NONFINSYLHD. Thus both *.wi.ţe.* and *.wi.ţ□́.⟨e⟩* violate NONFINSYLHD equally. The analysis *.wi.ţ□́.⟨e⟩*, which both truncates and augments, has additional marks *ALIGN, *PARSE, and *FILL^{Nuc}, which will sink it no matter where those constraints are ranked. It now follows that simple augmentation cannot coexist with truncation, without having to specify a ranking between FILL^{Nuc} and the constraint that drives truncation — an attractive result. This analysis successfully embodies the idea that augmentation does not go with truncation for the simple reason that augmentation merely recreates the structure that truncation serves to eliminate. Furthermore it releases FILL^{Nuc} from having to dominate ALIGN, so that it can join FILL^{Ons} in a contiguous package of Faithfulness constraints, perhaps simplifying the overall structure of the analysis.

The problem with the proposal is that NONFINSYLHD faces yet another method of circumvention: *closing* the final syllable with an empty Coda. The aimed-for optimum *.wi.ţe.* now faces other competitors: *.wi.ţe□.* and *.wi.ţ□́□.⟨e⟩*. (Notice that the coda-epenthesized form does not satisfy FREE-V and so is not a serious competitor in the analysis proposed in the text.) Depending on details of formulation, one or both of these candidates are likely to satisfy NONFINSYLHD, which *.wi.ţe.* fails. (A similar issue arises with respect to whole-syllable augmentation: *.maŗ.*□□́□. now begins to look better than *.maŗ.*□́□.) Since NONFINSYLHD must dominate ALIGN to allow e.g. *muŋ.ku.mu.⟨ŋku⟩* — ALIGN favors the parsing of stem-final material —, the coda-epenthesized forms cannot be allowed to triumph through victory on NONFINSYLHD.

The issue appears to demand a principled resolution, since syllable amplification is not a well-known response to constraints of the NONFINALITY family. Pending such resolution, we put the matter aside, noting the promise of the approach, both conceptually (it brings truncation into the purview of NONFINALITY) and analytically (it affects the structure of Lardil grammar in ways that may count as simplification).

ALIGN is involved in one last ranking. This constraint forces certain forms to be augmented by an entire empty syllable, rather than by a partly empty one. An extra empty node is needed to complete the empty syllable; FILL violation is driven beyond its absolute minimum. The crucial examples are cases like *.maɽ.*□□́. where the stem-final consonant *ɽ* is a possible coda. Compared to the alternative **.ma.ɽ*□́., the optimal parse has an additional mark *FILL^{Ons}. In order that the FILL^{Ons} defect be rendered harmless, we must have dominant ALIGN.

(177) **Augment with Complete Syllable**
ALIGN ≫ FILL^{Ons}

The following tableau lays it out:

(178) **ALIGN compels extra structure**

/maɽ/ →	ALIGN	FILL^{Ons}
☞ .maɽ.□□́.		*
.ma.ɽ□́.	* !	

We have now determined a set of domination relations between pairs or triples of constraints by considering candidate comparisons where they conflict. These constraint dominations are *necessary* in order that the overall constraint ranking be consistent with the Lardil facts. If any one of these dominations failed to hold, then the conflicts we have examined would be resolved differently, and an actual Lardil parse would be less harmonic than at least one competitor, and it could not appear in the output of the grammar.

At this point in the analysis we must combine these necessary domination relations to determine whether they are consistent with some single constraint domination hierarchy. Then we must check that such a hierarchy is logically *sufficient* to explain the Lardil facts. This final step is required because in establishing each two- or three-way domination relation, we have only examined one input and one competitor to the actual Lardil parse. It remains to demonstrate, for the entire spectrum of inputs, that the Lardil parse is more harmonic than all competing parses, when all constraints are taken into consideration simultaneously.

The constraint domination relations we must now unify into a hierarchy are those in (165–169, 171–172, 176–177). The unification is performed incrementally in the following table, working down the hierarchy, starting with the superordinate constraints.

(179) **Lardil Constraint Hierarchy Derived:**

Constraint		Ranking Justification		Remarks
*COMPLEX, CODACOND, ONS, FTBIN, LX≈PR	≫	None crucially dominated	(165)	All are unviolated. All force violations.
FILL^{Nuc}	≫	LX≈PR ≫ FILL^{Nuc}	(168)	Empty Nuc to meet word minimality
FREE-V	≫	FILL^{Nuc} ≫ FREE-V	(176)	Truncation & augmentation don't mix
ALIGN	≫	FREE-V ≫ ALIGN	(172)	Final V ***is*** free
FILL^{Ons}	≫	ALIGN ≫ FILL^{Ons}	(177)	Whole empty σ possible to get ALIGN
PARSE	≫	FILL^{Ons} ≫ PARSE	(166)	Avoid hiatus by nonparsing of V
–COD		PARSE ≫ –COD	(167)	Admit codas

Note that this overall ranking is consistent with the following five domination relations, which were established above in (166–171) as necessary, but which are not among the six used to deduce the hierarchy in (179):

ONS	≫	PARSE	(166)	Avoid Hiatus by nonparsing of V
FILL^{Nuc}	≫	–COD	(167)	Don't make potential codas into onsets
LX≈PR	≫	FILL^{Ons}	(168)	Can use whole empty σ to get minimal word
LX≈PR	≫	FREE-V	(169)	Don't truncate minimals
FREE-V	≫	PARSE	(171)	Final V **is** free

Of the undominated constraints, we have provided specific evidence for the ranking of FTBIN and LX≈PR above FILL^{Nuc} (168), and for the ranking of ONS above PARSE (166). *COMPLEX and CODACOND could in principle be enforced by breach of FILL^{Nuc} (with epenthesis to resolve the problematic consonant cluster) or of PARSE (with deletion of one of the cluster members). Because FILL^{Nuc}≫PARSE is required, it follows that PARSE violation will the least serious infraction in any choice where both are at play. Therefore, *COMPLEX and CODACOND must crucially dominate only PARSE. We will not emphasize this refinement, however, and we will persist in representing all undominated constraints as grouped together at the top.

7.3 Verification of Forms

In §7.2 we examined interactions among a few constraints at a time, working from pairwise candidate competitions over which the constraints were in conflict. We thereby determined a set of relative domination relations each relating two or three constraint, and we then unified these into the constraint hierarchy (179). If any hierarchy of the constraints in (164) can account for the Lardil facts, it must be *this* one. ("This one", that is, up to re-rankings between nonconflicting constraints, which will involve those in the top-ranked group of table (179); see the discussion following that table.) We arrived at this conclusion by showing, in a variety of cases, that a desired optimum was better than one of its competitors. To show that the desired optimum is in fact *optimal* and uniquely so, we must establish that it is better than all of its competitors. In addition, we must determine whether this hierarchy correctly generates the complete set of alternations under scrutiny. We will consider the cases summarized in (159) in turn, and check that the actual Lardil parse is indeed optimal in each case, as determined by the constraint hierarchy (179).

It should be noted that global verification is not a new kind of burden imposed on grammarians by the present approach. Generative theories of phonology with rule-ordering, assignment of rules and constraints to various levels, specification of triggering and blocking relations, repair strategies, persistent rules and so on, give rise to complex systems that are often argued for on the basis of small-scale interactions. These grammars too can be left unverified overall only at the analyst's peril. In Optimality Theory, as in all interactionist theories, it is important to verify the analysis because interactions often arise which are not obvious to local inspection — indeed, this must be so, because getting interesting consequences from simple assumptions is the very rationale for interactionism.

In the verification arguments presented here, we will employ a useful methodology for testing the predictions of Optimality Theoretic grammars. To verify that a domination hierarchy yields the correct output, it is necessary to show that all competing analyses of the input are all less harmonic than the correct analysis. This requires a clear grasp of Gen, and control of a method for establishing optimality. The method we will use is this:

(180) **The Method of Mark Eliminability**

To show that a particular analysis is optimal, consider each of its marks *m*, and show that any way of changing the analysis to eliminate *m* results in at least one worse mark.[63]

We proceed systematically through the summary of patterns provided in (159), starting with the C-final stems.

[63] The logic behind this method is given by the Cancellation/Domination Lemma, stated in (192) and (238), of §8, p.142 and p.162, and proved in §A.1 of the Appendix.

7.3.1 Consonant-Final Stems

Stems ≥ μμ. Stem-final consonants, in stems ≥ μμ, non-sub-minimals, are parsed if they satisfy the coda constraint, unparsed otherwise. Examples (159.a–b) are treated in the following tableau:

(181) **Consonant-Final Stems ≥ μμ**

	*COMPLEX,FTBIN **CODACOND**, ONS, LX≈PR	FILL^{Nuc}	FREE-V	ALIGN	FILL^{Ons}	PARSE	−COD
A. i. ☞ .ken.ta.pal.							* *
ii. .ke.n□́.ta.pa.⟨l⟩		*!		*		*	
B. i. ☞ .wa.ŋal.⟨k⟩				*		*	*
ii. .wa.ŋalk.	*! [*COMPLEX] *! [CODACOND]						*
iii. .wa.ŋal.k□́.		*!		*			*
C. i. ☞ .ŋa.lu.⟨k⟩				*		*	
ii. .ŋa.luk.	*! [CODACOND]						*

When the stem-final consonant satisfies CODACOND, as in /kentapal/, it appears as a coda in the optimal parse (181.A.i). Optimality is readily established. The only marks against (181.A.i) are the two *−CODs, incurred from parsing *n, l* as codas. Any more harmonic parse would have to eliminate one or both these marks.

•To do so by failing to parse either segment violates the higher- ranked PARSE constraint.

•To parse either *l* or *n* as an onset would require positing an empty nucleus node after it, violating higher-ranked FILL^{Nuc}.

A competitor combining these attempts is shown in (181.A.ii.), along with the marks which show it to be less harmonic than the correct output.

This provides a concrete example of the general analysis in §6 showing that codas are possible when −COD ranks lower than both PARSE and FILL^{Nuc}. The basic syllable theory analysis applies without modification, because the only constraints coming into play are those of the basic theory, plus ALIGN, which provides a further incentive to parse a stem-final consonant as a Coda.

Henceforth, we will not comment on the violation marks *−COD that may be incurred in parses claimed to be optimal, since, as we have just seen, any attempt to avoid such marks always leads to more serious violations. Since −COD violations do not play a decisive role in the competitions of interest, we will omit −COD from all further tableaux.

A further constraint comes into play when the final consonant is not a pure coronal, for in that case parsing it as a coda violates CODACOND. We see that in the optimal parse of /waŋalk/ (181.B.i), the final *k* is *not* parsed, thereby violating both PARSE and ALIGN. This analysis is nonetheless optimal.

•The only way to avoid both these marks is to parse the final *k* as a coda (181.B.ii), violating the highest-ranked *COMPLEX and CODACOND.

•Trying to rescue the *k* by putting it in the onset of a final syllable with an empty nucleus (181.B.iii) still incurs the mark *ALIGN, and trades *PARSE for the worse mark *FILL^{Nuc}.

The same argument applies in the case of /ŋaluk/ (181.C.i-ii). The difference is only that the penultimate segment is a vowel rather than a possible coda consonant, so the optimal form doesn't violate −COD and the competitor doesn't violate *COMPLEX. This doesn't affect the conclusion, since any attempt to parse the *k* still violates CODACOND (when parsed as a coda) or FILL^{Nuc} (when parsed as an onset), both worse than *PARSE and *ALIGN.

Stems < μμ. With sub-minimal stems the constraints Lx≈Pr and FtBin come into play, as shown below in the tableau (182), which displays examples from (159.c−e). Satisfying these constraints requires positing a second syllable with at least one empty position (namely, Nuc).

(182) **Subminimal Consonant-Final Stems**

	*Complex, CodaCond, Ons, FtBin, **Lx≈Pr**	Fill^{Nuc}	Free-V	**Align**	Fill^{Ons}	Parse
A. i. ☞ .maŗ.□□́.		*			*	
ii. .maŗ.	*! [Lx≈Pr]					
iii. .ma.ŗ□́.		*		* !		
B. i. ☞ .ŗel.k□́.		*		*		
ii. .ŗel.⟨k⟩	*! [Lx≈Pr]			*		*
C. i. ☞ .ya.k□́.		*		*		
ii. .yak.□□́.	*! [CodaCond]	*			*	
D. i. ☞ .kaŋ.□□́.		*			*	
ii. .ka.ŋ□́.		*		* !		

In the first example, /maŗ/, the optimal parse (182.A.i) violates Fill^{Nuc}, Fill^{Ons}, and −Cod [omitted].

•Any attempt to avoid the worst mark, *Fill^{Nuc} will have to give up on the possibility of a second syllable, as in the faithful parse (182.A.ii). This fatally violates Lx≈Pr or FtBin, since the monosyllabic parse does not admit binary feet. To avoid violating Lx≈Pr or FtBin, it is necessary to posit an empty Nuc node; we need only consider such parses, then, when seeking optimal parses.[64] All such parses incur the mark *Fill^{Nuc}, so we can therefore ignore this mark in subsequent

[64] Lardil does not employ vowel lengthening to parse subminimal stems as bimoraic feet. For discussion of the constraints relevant to this limitation, see Black 1991, Piggott 1992, Itô & Mester 1992. As argued in McCarthy & Prince 1993 for the parallel case of Axininca Campa, vowel-lengthening is already ruled out for stems CV, because of Align; the pattern .CV.□□́. preserves MWord/syllable alignment while .CV□. destroys it. For Lardil, this is 50% welcome: we have ŗu.𝕎𝔸. but .t^ya𝔸, of which the latter remains inexplicable on the present account (unless it is underlyingly /t^y/).

More generally, Lardil does not use any kind of internal epenthesis to satisfy minimality requirements. Thus, from /maŗ/ we could expect either *.ma□ŗ.* with a long vowel, or bisyllabic *.ma.□□́ŗ.* or *.m□́.□aŗ.*, both of which are properly aligned. Although the *.ma□ŗ.* type is cross-linguistically attested (see McCarthy & Prince 1986, Lombardi & McCarthy 1991) and therefore suitable for being controlled by a rankable constraint, internal syllabic augmentation appears to be unknown and therefore requires a deeper and more stable explanation.

comparisons. (Note that the null parse, in which no segment is parsed, violates LX≈PR and cannot therefore be optimal.)

•The remaining two marks of the parse (182.A.i), *FILL^{Ons} and *−COD, can both be avoided by parsing the stem-final consonant *ɽ* not as a Coda but rather than as an Onset (182.A.iii). Parsing *ɽ* as an Onset violates ALIGN, fatal because the mark *ALIGN outranks the marks *FILL^{Ons} and *−COD that would thereby be avoided. It follows that form (182.A.i) is optimal.[65]

The situation changes, though, when the stem-final consonant (or cluster) is not a legal coda. Now the final consonant is optimally parsed as an onset. With /ɽelk/ (182.B) and /yak/ (182.C), parsing the final *k* as an onset violates ALIGN, but there is no alternative that is more harmonic. This mark *ALIGN could only be avoided by analyzing final *k* as a Coda, which would violate the superordinate constraint CODACOND (and in (182.B) also *COMPLEX) — yielding a less harmonic parse.

It is instructive to compare the fate of the final *k* in /ɽelk/ (182.B) to that in /waŋalk/ (181.B). In the longer word, the final *k* is not parsed (incurring *PARSE), whereas in the sub-minimal case, the *k* is parsed as an Onset (incurring *FILL^{Nuc}).

When LX≈PR and FTBIN are not involved, as with /waŋalk/, the fact that FILL^{Nuc} dominates PARSE entails that nonparsing of *k* is optimal, since *PARSE is the lower-ranked mark. Syllabic well-formedness is achieved through omission of refractory segmental material, rather than through supplying empty structure to support it. But when undominated LX≈PR and FTBIN become relevant, as with /ɽelk/, they mask the fact that FILL^{Nuc} dominates PARSE, and the result reverses. In the competing analyses of /ɽelk/ in (182.B), it is no longer relevant that PARSE is dominated by FILL^{Nuc}, since the low-ranked PARSE violation now comes along with a superordinate failure on LX≈PR or FTBIN, the minimality enforcers.

The final case of /kaŋ/ (182.D) works just like the first case (182.A) of /maɽ/, given proper formulation of CODACOND, a matter discussed in fn. 60, p.113.

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[65] Recall that *.maɽ*.□□́. is distinguished from .□□́.*maɽ*. on the grounds of proper alignment, as discussed in §7.1, p. 114. By ALIGN in the text we mean ALIGN−R, pertaining to final edges. It is LX≈PR, construed in the Chen-Selkirk manner as requiring initial-edge alignment, that rules out prothesis.

7.3.2 Vowel Final Stems

Stems > μμ. The most aggressive truncations in Lardil are observed with supraminimal vowel-final stems. The final vowel is unparsed, as are all the preceding consonants which cannot be parsed as codas without violating CodaCond. The examples from (159.f-g) illustrating one, two, and three final unparsed segments are treated below in the tableau (183).

(183) **Supra-Minimal Vowel-Final Stems**

		*Complex, CodaCond, Ons, FtBin Lx≈Pr	Fill^{Nuc}	**Free-V**	Align	Fill^{Ons}	Parse
A. i. ☞	.yi.li.yil.⟨i⟩				*		*
ii.	.yi.li.yi.li.			* !			
B. i. ☞	.yu.kař.⟨pa⟩				*		* *
ii.	.yu.kařp.⟨a⟩	*! [*Complex] *! [CodaCond]			*		*
iii.	.yu.kař.p□́.⟨a⟩		* !		*		*
C. i. ☞	.ŋa.wu.ŋa.⟨wu⟩				*		* *
ii.	ŋa.wu.⟨ŋawu⟩				*		* * * ! *
D. i. ☞	.muŋ.ku.mu.⟨ŋku⟩				*		* * *
ii.	.muŋ.ku.muŋ.⟨ku⟩	*! [CodaCond]			*		* *

Most striking here is the way that the domination hierarchy permits such flagrant violations of Parse as those observed in *.muŋ.ku.mu.⟨ŋku⟩*, while controlling these violations so that in each case only the correct number of segments are left unsyllabified.

Parse is ranked low enough in the hierarchy so as to be out-ranked by several constraints which conflict with it: relevantly, CodaCond, Fill^{Nuc} and Free-V. With these three in dominant position, it is optimal to leave segments out of syllable structure (*Parse) if

- for vowels, parsing them violates Free-V

- for consonants, assigning them to coda position violates CodaCond or assigning onset status violates Fill^{Nuc}.

On the other hand, while ranked low, PARSE is nonetheless operative in Lardil grammar (as in every grammar). Any failure to parse which is not required to meet a higher-ranked constraint renders the overall parse less harmonic, due to the avoidable marks *PARSE thereby incurred.

To see how these constraint interactions play out in the actual cases, consider first /yiliyili/ (183.A). The optimal parse incurs the marks *ALIGN, *PARSE, and *−COD (the last being unmentioned in the tableau).

•To avoid the two highest marks, *ALIGN and *PARSE, the final segment would have to be parsed. But this would violate FREE-V, a higher-ranked constraint (183.A.ii).

•As mentioned above in the discussion of (181.A), the lowest mark *−COD, cannot be avoided without incurring higher marks, because the constraints *FILL^{Nuc}, PARSE, and *−COD are ranked in a pattern characteristic of coda-permitting languages (167),p.121.Thus (183.A.i) is optimal.

The relative overall Harmonies of *.yi.li.yil.⟨i⟩* (183.A.i) and *.yi.li.yi.li.* (183.A.ii) pointedly illustrate the *strictness* of strict domination. Fully parsed *.yi.li.yi.li.* is less harmonic than truncated *.yi.li.yil.⟨i⟩* even though it violates only one constraint, while the truncated form violates three of the four lower-ranked constraints (including −COD). Indeed, a form like *.yi.li.yi.li.* would seem on first glance to be a perfect parse, consisting as it does entirely of optimal CV syllables, and constituting a perfectly faithful parse in which underlying segments are in one-to-one correspondence with syllable positions. Such is the strength of FREE-V in Lardil, and of the strictness of strict domination, that the sole mark *FREE-V renders the form less harmonic than the optimal output, which violates fully three of the four constraints ranked lower than FREE-V.

The fate of the stem /yukařpa/ (183.B) is almost identical to that of /yiliyili/ (183.A), the only difference being that in the optimal parse, the penultimate consonant (*p*) remains unsyllabified.

•The attempt to avoid *ALIGN and *PARSE by syllabifying the final vowel violates higher-ranked FREE-V, just as with /yiliyili/.

•Attempts to save the penultimate consonant, and thereby remove the second *PARSE mark, must also decrease Harmony. Parsing *p* with *ř* in a single coda (183.B.ii) violates the superordinate constraints *COMPLEX and CODACOND. Parsing it as an onset (183.B.iii) requires a following empty Nuc node, thus incurring a mark *FILL^{Nuc} which is worse than the mark *PARSE thereby avoided.

The stem /ŋawuŋawu/ (183.C) is identical in all relevant respects to /yukařpa/ (183.B) except that the antepenultimate segment is a vowel; in the optimal output, the last parsed segment is a vowel. The proof of optimality is virtually the same as that just given.

The resulting phonetic form [ŋawuŋa] is vowel-final; derivational accounts with a final-vowel-deletion rule (as in previous interpretations of the phenomenon), must ensure that this rule cannot reapply to further delete the now-final *a* and, presumably, with it the preceding illicit coda consonant *ŋ*. This would result in the form [ŋawu], which is subject to further truncation, blocked then by a minimal word constraint. In (183.C.ii) we show the competing output [ŋawu], phonologically, *.ŋa.wu.⟨ŋawu⟩*, to allay any fears that such iterated truncation, with more than one vowel unparsed, can arise to plague the present account. Because the second *a* is not a *word-final* vowel, it plays no role in assessing violations of FREE-V. Parsing it (183.C.i) is quite irrelevant to the constraint FREE-V. Consequently, the additional mark *PARSE that results from leaving it unparsed (183.C.ii) is entirely unjustifiable, as it avoids no other marks. The additional PARSE violation is fatal to the overtruncated [ŋawu].

The conclusion still holds if the preceding consonant were not *ŋ* but, say, *n*, which could safely be parsed as a coda, thereby eliminating the fourth *PARSE mark from (183.C.ii). The fourth mark is superfluous; the third *PARSE incurred by not parsing *a*, a single step beyond necessity, is sufficient to decide the competition.

The final example *.muŋ.ku.mu.⟨ŋku⟩* (183.D) works just like the others. It is of some interest that the antepenultimate segment *ŋ* is unparsed even though it is followed by *k*. In a derivational account, the sequence of rules which accounts for this is: delete final vowel *u*, delete illegal coda consonant *k*, delete illegal coda consonant *ŋ*. These steps are serially ordered, since prior to deleting *u*, the *k* is parsable as an onset; and prior to deleting *k*, the *ŋ* is parsable as a coda. In the present account, there is no derivational sequence and no deletion. The entire final parse is evaluated once and for all; everything follows from the primary syllabification of the input string. In the optimal analysis, *u* is not syllabified; neither is *k*; nor *ŋ*. Parsing any or all of these segments introduces violations of the constraints on syllabification and on the morphology/prosody relation, violations more serious than the three *PARSE marks incurred by not syllabifying the segments in question. The one case not seen before is the alternative of parsing only *ŋ*, shown in (183.D.ii). The undominated constraint CODACOND is violated because the coda *ŋ* is linked to no following onset. There is an appropriate underlying *segment*, of course: *k*; but in the total parse under evaluation, there is no following *Onset*.

Stems = μμ. Unlike longer stems just reviewed, those vowel-final stems which are exactly minimal must have their final vowel parsed. The example (159.h) is shown in the following tableau:

(184) **Minimal Vowel-Final Stems**

	*COMPLEX, CODACOND,FTBIN ONS, **LX≈PR**	FILL^{Nuc}	FREE-V	ALIGN	FILL^{Ons}	PARSE
i. ☞ .wi.ţe.			*			
ii. .wiţ.⟨e⟩	*! [Lx≈Pr]			*		*
iii. .wiţ.□□́.⟨e⟩		* !		*	*	*
iv. .wi.ţ□́.⟨e⟩		* !		*		*

In minimal stems, FREE-V conflicts with LX≈PR and FTBIN. The optimal parse violates FREE-V, because failing to parse the final vowel leads to violation of LX≈PR or FTBIN (184.ii), unless empty nodes are also posited. Such empty nodes are optimal in sub-minimal consonant final stems (182), and we must consider them here. In (184.iii), *ṭ* is parsed as a Coda and followed by an empty Onset and Nucleus; in (184.iv), *ṭ* is parsed as an Onset and followed by an empty Nucleus. In both cases, the high-ranking mark *FILL^{Nuc}, absent in the optimal parse, proves fatal.

7.4 Discussion

Several features of the analysis deserve specific comment.

Grammar building. The typical result in Part I involves the ranking of only a few constraints. The Lardil analysis shows that the formal principles laid out in Part I apply smoothly and without enrichment to an intricate grammatical system. Other work in the theory offers similar demonstrations; we refer the interested reader to the works cited at the end of §1.

Pitfalls of pre-theoretic intuitions of Harmony. Lardil *Final Vowel Deletion* is taken by Goldsmith (1993) to be a plainly 'anti-harmonic rule' — one whose application *reduces* the Harmony of the representation. This construal motivates his proposal that linguistic derivations involve a set of non- or even anti-harmonic rule applications between levels, in addition to serial harmonic rule applications within levels.

Harmonic rule application is characterized as follows: "… phonological rules apply … just in case their output is better than their input with respect to some criteria specified by a phonotactic (of the relevant level)" (Goldsmith 1993:252). He then observes that "word-final vowels are perfectly satisfactory" in Lardil. Since there is no *phonotactic* involved — no descriptively-true generalization about surface word structure — he is led to conclude that harmonic considerations are irrelevant. The claim is, of course, untenable: the truncation pattern respects minimality limitations that are the direct consequence of prosodic well-formedness constraints (Wilkinson 1986, 1988).

Although we have full sympathy with the general programmatic notion that harmonic considerations are central to the assignment of linguistic form, we suggest that the problem with the Goldsmith proposal for Lardil lies in its reliance on pre-theoretic notions of Harmony, which are simply too ill-defined to provide much of a guide to real-world complexities. Although it seems reasonable that rules ought to apply when their output is better "with respect to some criteria specified by a phonotactic," in realistic situations the output is just as likely to be *worse* by some criteria specified by other phonotactics, and this worseness can very well be crucial. And, if we are right about the universality and generality of constraints, the motivating factors are unlikely to be limited to anything as parochial as a phonotactic presumably is.

Goldsmith states, plausibly, that "the bulk of phonological rules apply in order to arrive at representations that *maximally satisfy constraints* (or, equivalently, schemata) that involve structuring phonological information [emph. supplied]." But without a well-defined notion of what it is to *maximally satisfy* a set of potentially conflicting constraints, there is in general no way to ascertain whether a given process is harmonic or the direct opposite; intuition, even steeped in scholarship, offers no sure guide.

In the account developed here, the Harmony of the Lardil analysis is defined in such a way that supra-minimal words with final unparsed vowels are *more* harmonic than those with final parsed vowels. In the appropriate theoretical framework, then, we can formally acknowledge a constraint, FREE-V, which asserts that, all other things being equal, leaving word-final vowels unparsed is optimal. This constraint not only fits into the overall constraint hierarchy of Lardil, along with other pre-theoretically more intuitive constraints; it is recognizable (indeed, as is already observed in Wilkinson 1986) as a slightly peculiar member of a universal family of 'extrametricality' constraints, which deal with the nonfinality of prominence. Understood in this way, its interaction with minimality considerations — patently harmonic in character — is entirely expected.

Relevance of the Basic Syllable Structure Theory. The Basic Syllable Structure Theory assumes a certain level of idealization in order to explicate fundamental universal aspects of syllable structure theory. Nonetheless, it forms without modification a crucial sub-structure within the Lardil analysis, indicating that further progress in developing and applying the syllable theory can proceed by addition to the basic module rather than by catastrophic renovation of its premises.

Relation between universal and language-particular phonology. The Basic Syllable Structure constraints and the additional constraints brought forth in the Lardil analysis are either strictly universal or mildly parametrized versions of recognizably universal constraints. The general approach to typological analysis exemplified by the Basic Syllable Structure Theory, like the substantive content of its constraints, is carried over intact into the more richly detailed context of Lardil. As promised in our characterization of the theory, Universal Grammar provides a set of constraints (some parametrized) and the primary mechanism of cross-linguistic variation is the different dominance rankings which are chosen by individual languages.

Generalization patterns. All decisions required to determine the correct analysis of a given stem are handled by the single notion of constraint domination. This includes interactions that would be described in other accounts as involving *constraints* and *rules*, ontologically quite different and with problematic interaction. A complete explication is given for how a constraint can appear to trigger or block the application of a rule. Such effects are handled by the same mechanism that handles basic syllabification and all other components of structural analysis: maximizing Harmony, as defined through a constraint hierarchy.

Strictness of strict domination. In several examples the correct analysis violates many constraints, and its optimality rests crucially on the fact that competitors with a cleaner record overall happen to violate some single dominant constraint. Recall the discussion of /yiliyili/ in §7.3.2: a strong contender violating just one constraint is bested by an optimal parse violating three of the four less dominant constraints. This effect highlights the content of the central evaluative hypothesis of Optimality Theory, and sets the theory apart from others in which richer notions of 'weighting' and 'trade-off' are entertained.

Parallelism and representation. The theory operates by evaluating a total candidate parse, which contains the underlying form, over the entire constraint hierarchy. This non-sequential approach offers at least two advantages in the Lardil analyis. First, since the underlying form is present in the structure being evaluated, the status of a vowel as word- or stem-final does not change; thus the constraint FREE-V can unproblematically refer to word-final vowels. This constraint is then *not* violated by the plethora of Lardil forms containing phonetically final vowels that are not phonologically final, analyses where the last parsed segment is a vowel which is followed by unparsed segments. This eliminates the issue that arises in serial theories of whether a rule of *Final Vowel Deletion* can reapply during the derivation (see the discussion of /ŋawuŋawu/ in §7.3.2).

The second advantage involves the parallel assessment of constraints on a total analysis. Consider the stem /kaŋ/, which is analyzed as .*kaŋ*.□□́., phonetic [kaŋka] (183.D.i). As observed in Kirchner 1992a, serialist theories have difficulty explaining how *ŋ* surfaces as a coda.

Suppose there are rules *Syllabification* and *Augmentation* that must apply in sequential steps. Syllabification must have a chance to apply before Augmentation in order to establish the needed distinction between /maŗ/ → [.maŗ.ţa.] (183.A.i), in which the stem forms a syllable, and /yak/→ [.ya.ka.] (183.C.i), in which the stem-final consonant is attached to the next syllable over. Augmentation inserts an onset only when the stem-final consonant is *already* parsed as a coda.

Now consider /kaŋ/. When Syllabification applies, the *ŋ* is no more syllabifiable as a coda than the *k* of /yak/ — *ŋ* can only be a coda when linked to a following onset. The situation is obviously not improved by trying to allow Augmentation to precede Syllabification, with the aim of making it possible for *ŋ* to be syllabified as a coda, for then it would be unclear why stem-final consonants should ever be parsed as anything but onsets. In short, Syllabification and Augmentation are mutually interdependent: each 'triggers' the other. Augmentation triggers the syllabification of a coda, which itself triggers the insertion of an Onset (which itself triggers coda-syllabification, which itself …). This kind of ordering pathology is an artifact of the derivational treatment, which resembles but exceeds in severity the problems discussed above for Bottom-Up Constructionism in prosodic theory. Interestingly, it is not resolvable by allowing Syllabification to apply *freely* in a serial derivation, an approach which Itô 1986 successfully uses to solve other similar problems. We conclude that the coincidence of stem and syllable edges cannot be successfully derived from serial (including cyclic) application of syllabification rules.

When all of the relevant constraints are assessed in parallel, as in Optimality Theory, an entire completed parse is subject to evaluation. At the point where the status of *ŋ* as a licit coda is judged, each candidate analysis has already committed once and for all to the presence or absence of a following Onset node. The necessity of this kind of information flow is a key prediction of the present theory, and a number of further cases of crucial parallelism are discussed in McCarthy & Prince 1993. The crux of the matter is that the grammar must determine which *total* analysis is well-formed — a task impeded by the use of serial algorithms to build structure step-by-step.

8. Universal Syllable Theory II: Ordinal Construction of C/V and Onset/Coda Licensing Asymmetry

Syllabification must reconcile two conflicting sources of constraint: from the bottom up, each segment's inherent featural suitability for syllable peak or margin; and from top down, the requirements that syllables have certain structures and not others. The core conflict can be addressed in its most naked form through the idealization provided by CV theory. Input C's need to be parsed as margins; input V's need to be parsed as peaks. Syllables need to be structured as Onset-Peak-Coda; ideally, with an onset present and a coda absent. In the Basic Theory, only one input segment is allowed per syllable position. Problematic inputs like /CCVV/ are ones which bring the bottom-up and top-down pressures into conflict. These conflicts are resolved differently in different languages, the possible resolutions forming the typology explored in §6.

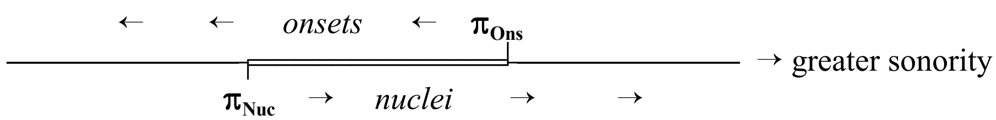
The CV theory gives some articulation to the top-down pressures: syllable shapes deviate from the Onset-Peak ideal in the face of bottom-up pressure to parse the input. By contrast, the bottom-up is construed relatively rigidly: C and V either go into their determined positions, or they remain unparsed. In real syllabification, of course, a richer set of possibilities exists. A segment ideally parsed as a peak may actually be parsed as a margin, or vice versa, in response to top-down constraints on syllable shape. One of the most striking examples of the role of optimality principles in syllabification, Tashlhiyt Berber (§2), exploits this possibility with maximal thoroughness. Berber syllabification on the one hand and CV syllabification on the other constitute extremes in the flexibility with which input segments may be parsed into different syllable positions in response to top-down pressure. In between the extremes lies the majority of languages, in which some segments can appear only as margins (like C in the CV theory), other segments only as peaks (like V), and the remaining segments, while ideally parsed into just one of the structural positions, can under sufficient top-down pressure be parsed into others.

In this section we will seek to unify the treatments of the two extremes of syllabification, Berber and the CV theory. Like the CV theory, the theory developed here will deal with an abstract inventory of input segments, but instead of just two abstract segments, each committed to a structural position, the inventory will consist of abstract elements distinguished solely by the property of *sonority*, taken to define a strict order on the set of elements. For mnemonic value we denote these elements *a*, *i*,…, *d*, *t*; but it should be remembered that all dimensions other than sonority are idealized away. In the CV theory, the universally superordinate constraints *M/V and *P/C prohibit parsing V as a margin or C as a peak. In the more realistic theory we now turn to, the corresponding constraints are not universally superordinate: the constraints against parsing any segment α as a margin (*M/α) or as a peak (*P/α) may vary cross-linguistically in their rankings. What universal grammar requires is only that more sonorous segments make more harmonic peaks and less harmonic margins.

From these simple assumptions there will emerge a universal typology of inventories of possible onsets, peaks, and codas. The inventories will turn out to be describable in terms of derived parameters π_{Ons}, π_{Nuc}, and π_{Cod}, each with values ranging over the sonority order. The margin inventories are the sets of segments *less* sonorous than the corresponding parameter values π_{Ons} or

π_{Cod}, and the peak inventory is the set of segments *more* sonorous than the value of π_{Nuc}. Languages in which $\pi_{Ons} > \pi_{Nuc}$ are therefore languages with ambidextrous segments, which can be parsed as either onset or nucleus. The following diagram pictures the situation; the double line marks the zone of overlap.

(185) **Languages with Ambidextrous Segments**



The theory entails a universal licensing asymmetry between onsets and codas: codas can contain only a subset, possibly strict, of the segments appearing in onsets. This fundamental licensing asymmetry will be shown to follow from the asymmetry between Onset and Coda in the Basic Syllable Structure Constraints. From the fact that Onsets should be present and Codas absent, it will follow in the theory that Coda is a weaker licenser.[66] To our knowledge, no other approach has been able to connect the structural propensities of syllables with the licensing properties of syllabic positions, much less to derive one from the other. This is surely a significant result, one that indicates that the theory is on the right track in a fundamental way. The exact nature of the obtained licensing asymmetry has some empirical imperfections which can be traced to the oversimplified analysis of codas in the internal structure of the syllable, and we suggest possible refinements.

The present section constitutes a larger-scale exploration of our general line of attack on the problem of universal typology. Universal Grammar provides a fixed set of constraints, which individual languages rank differently in domination hierarchies; UG also provides certain universal conditions on these hierarchies, which all languages must respect. The results obtained here involve a further development of the basic idea: *parametrization by ranking*. The parameters π_{Ons}, π_{Nuc}, and π_{Cod} are epiphenomenal, in that they do not appear at all in Universal Grammar, or indeed, in particular grammars: they are not, for example, mentioned in any constraint. These parameters are not explicitly set by individual languages. Rather, individual languages simply rank the universal constraints, and it is a *consequence* of this ranking that the (derived, descriptive) parameters have the values they do in that language. The procedures for reading off these parameter values from a language's constraint domination hierarchy are not, in fact, entirely obvious.

The analysis developed here introduces or elaborates several general concepts of the theory:

(186) **Push/Pull Parsing:** The parsing problem is analyzed in terms of the direct conflict between two sets of constraints:

a *ASSOCIATE* constraints

PARSE, FILL, ONS, and the like, which penalize parses in which input segments or structural nodes *lack* structural associations to a parent or child;

[66] The demonstration will require some work, however; perhaps this is not surprising, given the simplicity of the assumptions.

b *DON'T-ASSOCIATE* constraints
*M/V, *P/C, and −COD and their like, which penalize parses which *contain* structural associations of various kinds.

(187) **Universal Constraint Sub-Hierarchies:** The DON'T-ASSOCIATE constraints *M/V, *P/C, superordinate in the CV theory, are replaced by an articulated set of anti-association constraints *M/*a*, *M/*i*, …, *M/*d*, *M/*t*; *P/*a*, *P/*i*,…, *P/*d*, *P/*t* which penalize associations between Margin or Peak nodes on the one hand and particular input segments on the other. Universal Grammar requires that the domination hierarchy of each language rank these constraints *M/α, *P/α relative to one another in conformity with the following universal domination conditions:

$*M/a \gg *M/i \gg \cdots \gg *M/d \gg *M/t$ (Margin Hierarchy)
$*P/t \gg *P/d \gg \cdots \gg *P/i \gg *P/a$ (Peak Hierarchy)

The Margin Hierarchy states that it's less harmonic to parse *a* as a margin than to parse *i* as margin, less harmonic to parse *i* as a margin than *r*, and so on down the sonority ordering. The Peak hierarchy states that it's less harmonic to parse *t* as a peak than *d*, and so on up the sonority order.

(188) **Associational Harmony:** The universal Margin and Peak Hierarchies ensure the following universal ordering of the Harmony of possible associations:

$M/t \succ M/d \succ \cdots \succ M/i \succ M/a$
$P/a \succ P/i \succ \cdots \succ P/d \succ P/t$

These represent the basic assumption that the less sonorous an element is, the more harmonic it is as a margin; the more sonorous, the more harmonic it is as a Peak.

(189) **Prominence Alignment:** These universal rankings of constraints (187) and ordering of associational Harmonies (188) exemplify a general operation, Prominence Alignment, in which scales of prominence along two phonological dimensions are harmonically aligned. In this case, the first scale concerns prominence of structural positions within the syllable:

Peak > Margin

while the second concerns inherent prominence of the segments as registered by sonority:

$a > i > \cdots > d > t$

(190) **Encapsulation:** It is possible to greatly reduce the number of constraints in the theory by encapsulating sets of associational constraints *M/α, *P/α into defined constraints which explicitly refer to *ranges* of sonority. This corresponds to using a coarse-grained sonority scale, obtained by collapsing distinctions. This must be done on a language-specific basis, however, in a way sensitive to the language's total constraint hierarchy: which sets of associational constraints can be successfully encapsulated into composite constraints depends on how the language inserts other constraints such as PARSE, FILL, ONS, and so on, into the Margin and Peak Hierarchies, and how these two Hierarchies are interdigitated in the language. Encapsulation opens the way to developing a substantive theory of the sonority classes operative in syllable structure phenomena.

Along with these conceptual developments, this section introduces a collection of useful techniques for reasoning about constraint domination hierarchies in complex arenas such as that defined by the segmental syllable theory. A few of these techniques are:

(191) **Harmonic Bounding for Inventory Analysis:** In order to show that a particular kind of structure φ is not part of a universal or language-particular inventory, we consider any possible parse containing φ and show constructively that there is some competing parse (of the same input) which is more harmonic; thus no structure containing φ can ever be optimal, as it is always bounded above by at least one more-harmonic competitor. (This form of argument is used to establish the distribution of epenthesis sites in §6.2.3.)

(192) **Cancellation/Domination Lemma:** In order to show that one parse B is more harmonic than a competitor A which does not incur an identical set of marks, it suffices to show that every mark incurred by B is either (i) cancelled by an identical mark incurred by A, or (ii) dominated by a higher-ranking mark incurred by A. That is, for every constraint violated by the more harmonic form B, the losing competitor A either (i) matches the violation exactly, or (ii) violates a constraint ranked higher.

(193) **The Method of Universal Constraint Tableaux:** A generalization of the method of language-specific constraint tableaux is developed; it yields a systematic means for using the Cancellation/Domination Lemma to determine which parse is optimal, not in a specific language with a given constraint hierarchy, but in a typological class of languages whose hierarchies meet certain domination conditions but are otherwise unspecified.

Exposition proceeds as follows. In §8.1 we define the Basic Segmental Syllable Theory; using our analyses of Berber and the Basic CV Syllable Structure Theory as starting points, we develop most of the basic notions mentioned above, including Associational Harmony and Prominence Alignment.

The Basic Segmental Syllable Theory defined in §8.1 is then subjected to extended analysis in §8.2. The formal techniques mentioned above are introduced and applied, leading ultimately to a set of necessary and sufficient constraint domination conditions involving *M/α (or *P/α) which govern whether the segment α is a possible onset (or nucleus). Some nontrivial analysis is required, because we are answering the following nontrivial question: considering all possible orderings of (a fair number of) constraints, and considering all possible input strings, when is parsing some segment α as an onset more harmonic than all possible alternative parses? It is possible to skim the detailed analysis; this should suffice for reading the rest of §8, which is considerably less technical.

The necessary and sufficient conditions derived in §8.2 are then cashed in (§8.3) for a universal typology of inventories of onset and nucleus segments. We consider codas, and derive and discuss the onset/coda licensing asymmetry result. We also derive the procedures for extracting a language's parameters π_{Ons}, π_{Nuc}, and π_{Cod} from its constraint hierarchy.

In §8.4 we develop and briefly discuss the Encapsulated Segmental Syllable Theory.

Given that this section contains a considerable amount of analysis, it is worth taking a moment at the outset to see a bit more clearly why extended analysis is necessary to establish the results we will obtain. The most complex result is the onset/coda licensing asymmetry, which can be stated as follows:

(194) Cross-linguistically, the inventory of possible codas is a subset of the inventory of possible onsets, but not vice versa.

To see just what we'll need to show in order to establish this result, we will give a step-by-step reduction of (194) to the elements in terms of which it must actually be demonstrated:

(194) a. For all languages admitted by Universal Grammar, the inventory of possible codas is a subset of the inventory of possible onsets, but not vice versa.

b. For all constraint hierarchies $\mathbb{CH}$ formed by ranking the Universal syllable structure constraints as allowed by Universal Grammar, the inventory of possible codas is a subset of the inventory of possible onsets, but not vice versa.

c. For all rankings $\mathbb{CH}$ of the Universal syllable structure constraints allowed by Universal Grammar, and
    for all segments λ,
        if λ is a possible coda in the language given by $\mathbb{CH}$
        then λ is a possible onset in $\mathbb{CH}$,
but not vice versa.

d. For all rankings $\mathbb{CH}$ of the Universal syllable structure constraints allowed by Universal Grammar, and
    for all segments λ,
        if there is an input string I_λ
            containing λ
            for which the optimal parse (w.r.t. $\mathbb{CH}$) is one in which λ is associated to Cod,
        then there is an input string $I_\lambda{}'$
            containing λ
            for which the optimal parse (w.r.t. $\mathbb{CH}$) is one in which λ is associated to Ons;
but not vice versa.

e. **For all** rankings $\mathbb{CH}$ of the Universal syllable structure constraints allowed by Universal Grammar, and
    for all segments λ,
        if there exists an input string I_λ
            containing λ
            for which **there is** a parse $B_{\mathrm{Cod}/\lambda}$ in which λ is associated to Cod
            such that
                if C is any other candidate parse of I,
                then $B_{\mathrm{Cod}/\lambda}$ is more harmonic than C w.r.t the ranking $\mathbb{CH}$ ($B_{\mathrm{Cod}/\lambda} \succ_{\mathbb{CH}} C$),
        then there exists an input string $I_\lambda{}'$
            containing λ
            for which **there is** a parse $B_{\mathrm{Ons}/\lambda}{}'$ in which λ is associated to Ons
            such that
                if C' is any other candidate parse of $I_\lambda{}'$
                then $B_{\mathrm{Ons}/\lambda}{}'$ is more harmonic than C' w.r.t. the ranking $\mathbb{CH}$ ($B_{\mathrm{Ons}/\lambda}{}' \succ_{\mathbb{CH}} C'$);
but **not** vice versa.

In the final formulation, as in all the others, the phrase 'but not vice versa' means that if 'Cod' and 'Ons' are interchanged in the proposition which precedes, then the resulting proposition is false. The logical quantifiers and connectives in this assertion have been set in boldface in order to indicate the logical structure of the proposition without resorting to predicate calculus. The innermost embedded propositions ($B_{Cod/\lambda} \succ_{CH} C$, and likewise for the primed parses) are themselves somewhat complex propositions, defined in §5.1, which involve comparisons of the hosts of marks incurred by parses of entire strings.

The strategy pursued in this chapter is to approach the complexity inherent in such a result incrementally, demonstrating the onset/coda licensing asymmetry after accumulating a series of increasingly complex results on segmental inventories. We begin with the most fundamental notion, associational Harmony.

8.1 Associational Harmony

To move from the Basic CV Syllable Structure Theory to the Basic Segmental Syllable Structure Theory, we need to move from CV strings to segmental string inputs. All we will need to do, in fact, is to replace the CV association constraints *M/V (121) and *P/C (122), with constraints that are sensitive to the relative Harmonies of pairings between, on the one hand, different segments λ, and, on the other, structural nodes of type M (margin: Ons and Cod) or P (peak: Nuc). Thus we will need to replace *M/V and *P/C by constraints such as *M/λ and *P/λ which refer to particular segments λ. From these, we will reconstruct categories of segments which behave to first approximation as C and V do in the CV theory.

We have already seen in Berber the need to make the Harmony of P/λ associations sensitive to the sonority of λ; more sonorous segments make more Harmonic syllable peaks. This was embodied in the constraint HNUC; it was the central element in our Berber analysis and we claimed it to be an element of universal syllable structure theory. Now is the time to spell out this aspect of Harmonic syllable structure theory; considerable elaboration of the ideas is necessary, and we can motivate the necessary development by returning to Berber to inspect a minor detail the consequences of which for the general theory turn out to be substantial.

8.1.1 Deconstructing HNUC: Berber, Take 1

In our earlier analysis of Berber, we assumed that over- and under-parsing (a.k.a. epenthesis and deletion) are forbidden, that syllable positions are non-complex, and that onsets (except phrase-initially) are required. Together, these had the consequence that in certain cases even highly sonorous segments such as *i* and *u* will be parsed as onsets (and realized as *y* and *w*, respectively). It turns out, however, that the most sonorous segment, *a*, can *never* be parsed as a margin; it is the only segment in Berber that fails to be parsable both as an onset and as a nucleus. Since Berber morphology can in fact generate an input containing /*aa*/, one of our simplifying assumptions must give way; in fact, in this one situation, Berber tolerates overparsing, generating an empty onset, so that /aa/ → *.á.□á* (phonetically *aya*; Guerssel 1985).

We can apply the Basic Syllable Structure Theory results of §6 to incorporate this fact about /*a*/ into our Berber analysis as follows. The syllable structure is $\sum^{\mathrm{CV(C)}}{}_{\mathrm{ep}}$, so according to the Onset Theorem (136), since onsets are required, enforced via overparsing, we must have

(195) **Berber Onsets.** {ONS, PARSE} ≫ FILL$^{\mathrm{Ons}}$

By the Coda Theorem (138), since codas are not required, we must also have

(196) {FILL$^{\mathrm{Nuc}}$, PARSE} ≫ −COD.

The superordinate constraint *M/V (121) is replaced by

(197) ***M/*a*:** *a* must not be parsed as a margin.

The segment *a* is the one segment (like V in CV theory) that is so unacceptable as a margin that it is more Harmonic to posit an empty onset and thereby violate FILL$^{\mathrm{Ons}}$; thus we must have:

(198) **Berber Epenthesis.** *M/*a* ≫ FILL$^{\mathrm{Ons}}$ ≫ HNUC

That FILL$^{\mathrm{Ons}}$ must dominate HNUC follows from the fact that, aside from *M/*a*, no other constraint can force epenthesis; in particular, HNUC cannot; otherwise, an onset would be epenthesized before every underlying segment, allowing it to be parsed as a nucleus and thereby increasing nuclear Harmony.

Now corresponding to *P/C (122) in the CV theory, in our Berber analysis we have HNUC: Whereas *P/C says that C must not be parsed as a peak, HNUC gives an articulated scale for the Harmony of associations P/λ, governed by the sonority of λ. For now, then, we will replace *P/C by HNUC. As we have seen earlier, the onset requirement in Berber takes precedence over the forming of more Harmonic nuclei, but nuclear Harmony dominates avoidance of codas, so

(199) **Berber Onset/Nucleus/Coda Interaction.** ONS ≫ HNUC ≫ −COD

We can now assemble these relative domination conditions into a constraint hierarchy for Berber:

(200) **Berber Hierarchy:** {ONS, PARSE, FILL$^{\mathrm{Nuc}}$, *M/*a*} ≫ FILL$^{\mathrm{Ons}}$ ≫ HNUC ≫ −COD

Thus we see in the following tableau, for example, how /aa/ does indeed trigger epenthesis, whereas /ia/ or /ai/ or /tk/ does not (as usual, we are assuming that ONS in Berber treats the beginning of a phrase as an acceptable onset). Here, as elsewhere in this chapter, we analyze hypothetical inputs which contain only the material necessary to establish the analytical point at hand, factoring out irrelevant complexities and distractions.

(201) **Berber Exceptional Epenthesis**

	ONS	PARSE	FILL^{Nuc}	*M/*a*	FILL^{Ons}	HNUC	−COD
/aa/ →							
☞ .á.□á.					*	á á	
.aá.				* !		á	
.á⟨a⟩.		* !				á	
.á.á.	* !					á á	
/ia/ →							
☞ .iá.						á	
.í.□á.					* !	á í	
.ía.				* !		í	*
/ai/ →							
☞ .ái.						á	*
.á.□í.					* !	á í	
.aí.				* !		í	
/tk/ →							
☞ .tḱ.						ḱ	
.t□́k.			* !				*

While this solution is adequate descriptively, it is somewhat unsatisfactory explanatorily. For the constraint *M/*a* we have introduced expresses the markedness of *a* as a Margin; and of course the strong affinity of *a*, the most sonorous segment, for the Peak position is already expressed in HNUC. It seems no coincidence that it is *a* that has surfaced in a high-ranking constraint disfavoring Margin position, yet there is nothing in our theory so far that would have prevented, say, *M/*r* from having suddenly appeared in place of *M/*a*. It is almost as if HNUC were a *complex* of constraints governing the affinity of segments with varying sonority to the Peak and Margin positions — and while most of them are contiguous in the hierarchy, occupying the position we have marked HNUC, the strongest of them, pertaining to *a*, has detached itself from the rest and drifted above certain other constraints: crucially, FILL^{Ons}.

Now while the behavior of *a* is in a sense marginal in Berber — it is the only segment that cannot be parsed into both Peaks and Margins, and this fact only reveals itself in the event that an input contains /aa/ — such behavior is of course the *norm* in more typical languages; the class of segments that can fill both Peak and Margin positions in most languages consists of at most a few segments, whereas in Berber it consumes all the segments except *a*. So the need for high-ranking constraints such as *M/*a* in Berber will extend in most languages to the majority of segments; these constraints are primarily responsible for distinguishing consonants from vowels, as we shall now see, and they do a lot of work in typical languages. They function in the segmental theory as did *M/V (121) and *P/C (122) in the CV theory.

So the program now is to 'explode' HNUC into many segment-specific constraints like *M/*a*, so that those that need to may rise high in the domination hierarchy and prevent pure vowels from being parsed into Margins and pure consonants into Peaks. (In the sense intended here, Berber has one pure vowel, *a*, and no pure consonants.)

8.1.2 Restricting to Binary Marks

As a glance at the preceding tableau immediately reveals, HNUC stands out from the other constraints in its non-binarity; whereas the other constraints invoke a simple '*' when violated, HNUC is a graded constraint favoring more sonorous peaks. The explosion of HNUC now required, which liberates the like of *M/*a*, begins in fact as a recasting of the single, multi-valued HNUC constraint into a set of binary-valued constraints. Recall that

(202) **HNUC:** $\acute{a} \succ \acute{i} \succ \cdots \succ \acute{t}$ [generally, $\acute{\lambda} \succ \acute{\tau}$ if $|\lambda| > |\tau|$]

At this point it is convenient to rewrite this as follows:

(203) **Peak Harmony:** $\mathrm{P}/a \succ \mathrm{P}/i \succ \cdots \succ \mathrm{P}/t$

Now we can achieve this *Harmony scale* via an exactly corresponding *binary constraint hierarchy* of the form:

(204) **Peak Hierarchy:** $*\mathrm{P}/t \gg \cdots \gg *\mathrm{P}/i \gg *\mathrm{P}/a$

formed from the constraints:

(205) ***P/λ:** λ must not be parsed as a syllable Peak (i.e., associated to Nuc).

The tableau makes this equivalence clear:

(206) **HNUC Reduced to Binary Constraints**

	*P/*t*	···	*P/*i*	*P/*a*
P/*a* = á				*
P/*i* = í			*	
⋮		···		
P/*t* = t́	*			

If we take any two segments λ and τ with |λ| > |τ|, and compare their Harmonies using this constraint hierarchy, we see that $\acute{\lambda}' \succ \acute{\tau}$.

In anticipation of later analysis we point out that the Peak Hierarchy is not completely equivalent to HNUC. As far as the harmonic ordering of individual peaks is concerned, the two are indeed equivalent, but when entire parses containing multiple peaks are compared, a difference emerges. On whole parses, HNUC compares the multiple nuclei from most harmonic to least harmonic (as discussed in §5.2.1.2). The Peak Hierarchy, however, evaluates all violations in a parse of *P/*t* first, and so on down the Peak Hierarchy; and the violations of *P/*t* are incurred by the *least* harmonic nuclei. Thus the Peak Hierarchy evaluates whole parses by comparing the multiple nuclei from least to most harmonic. We will return to this issue in a later discussion of Berber in §8.3.3. In the meantime, we turn our attention to the consequences of the Peak Hierarchy for syllabification universally.

Paralleling this hierarchy of Peak association constraints, there is another hierarchy for Margins, with opposite polarity:

(207) **Margin Hierarchy:** *M/*a* ≫ *M/*i* ≫ ··· ≫ *M/*t*

The constraints here are in direct correspondence to the Peak counterparts (205):

(208) ***M/λ:** λ must not be parsed as a syllable Margin (i.e., associated to Ons or Cod).

The most dominant constraint, as promised in the earlier discussion of Berber, is *M/*a*. This Margin Hierarchy generates the following Harmony scale:

(209) **Margin Harmony:** M/*t* ≻ ··· ≻ M/*i* ≻ M/*a*

The single non-binary constraint HNUC and the Peak Hierarchy (204) of binary constraints each generate the same Harmony scale (203) for Nuc/segment associations (202). The power of the Peak Hierarchy is greater, however, since it will function as does HNUC to correctly rank all the peaks *regardless of whether all the constraints* *P/λ *are contiguous in the hierarchy*. That is, other constraints may be interspersed within the sequence prescribed by the Peak Hierarchy (204), and similarly for the Margin Hierarchy (207). This allows Berber, for example, to rank *M/*a* high in the hierarchy (200, 201) — crucially, higher than FILL^{Ons} — and all the other Margin constraints *M/*i* ≫ ··· ≫ *M/*t* lower than FILL^{Ons} in the hierarchy. This will (eventually) lead to another, more explanatory, analysis of Berber which is equivalent to the analysis in (200) and (201); cf. §8.3.3. More importantly, the separated association constraints of the Peak and Margin Hierarchies will enable us to handle the typological variation among languages in the degree of flexibility with which they permit segments to move between Margin and Peak positions.

The Peak and Margin Hierarchies exemplify a general treatment of the problem of producing Harmony scales in the association of two dimensions of structure D_1 and D_2, one of them binary, by "aligning" two pre-defined (non-Harmony) scales on D_1 and D_2. Here, D_1 is the binary structural dimension Peak/Margin, with the prominence scale:

(210) **Syllable Position Prominence:** P > M

and D_2 is the segment inventory with the prominence scale given by sonority:

(211) **Segmental Sonority Prominence:** *a* > *i* > ··· > *t*

(Recall that '*i*' denotes a sonority level, not a full bundle of distinctive features.) The process of *alignment* of these two prominence scales, (210) and (211), is an operation which by definition generates two Harmony scales on the associations between the two dimensions: precisely the two scales (203) and (209).

(212) **Alignment**

Suppose given a binary dimension D_1 with a scale X > Y on its elements {X, Y}, and another dimension D_2 with a scale a > b > ··· > z on its elements. The *harmonic alignment* of D_1 and D_2 is the pair of Harmony scales:

H_X: X/a ≻ X/b ≻ ··· ≻ X/z
H_Y: Y/z ≻ ··· ≻ Y/b ≻ Y/a

The *constraint alignment* is the pair of constraint hierarchies:

C_X: *X/z ≫ ··· ≫ *X/b ≫ *X/a
C_Y: *Y/a ≫ *Y/b ≫ ··· ≫ *Y/z

C_X and C_Y are to be understood as sub-hierarchies of a language's total constraint hierarchy; e.g., C_X asserts that scattered within the constraint hierarchy of a language are the constraints *X/z, ··· , *X/b, *X/a, and that they fall in that order (from most to least dominant), with other constraints possibly falling above, below, and among these constraints.

The idea of harmonic alignment is easily described in cases like the present one where the two scales are prominence scales along two dimensions (syllable structure and sonority): the more prominent position X prefers the more prominent elements (ideally, a); the less prominent position Y prefers the less prominent elements (ideally, z). Constraint alignment says that associating less prominent elements (like z) to the more prominent position X produces the most dominant marks; similarly for associating more prominent elements (like a) to the less prominent position Y.

As illustrated above (206), constraint alignment entails harmonic alignment; conversely, the constraints $*X/\alpha$ and $*Y/\alpha$ must be ordered according to constraint alignment if they are to be consistent with harmonic alignment. Thus there are two essentially equivalent ways to enter the alignment of two dimensions into Universal Grammar. The first is to assert that the constraint hierarchies C_X, C_Y of constraint alignment are universal, that they must be incorporated into the particular constraint hierarchy of any language. The second is to assert that the Harmony scales H_X, H_Y of harmonic alignment and the constraints $*X/\alpha$, $*Y/\alpha$ are universal; particular languages must order these constraints in a way consistent with H_X, H_Y. It then follows as a consequence that individual languages' constraint hierarchies will always contain the sub-hierarchies C_X, C_Y, i.e. satisfy constraint alignment.

We assume the following principle of Universal Grammar:

(213) **Universal Syllable Position/Segmental Sonority Prominence Alignment**
The syllable position (210) and segmental sonority (211) prominence scales are universally aligned: the harmonic alignments are the Peak (203) and Margin (209) Harmony scales; the constraint alignments are the Peak (204) and Margin (207) Constraint Hierarchies.

Note that while (213) fixes universally the relative Harmonies $P/\lambda \succ P/\tau$ and $M/\tau \succ M/\lambda$ (when $|\lambda| > |\tau|$), *it leaves the relative Harmonies of* P/λ *and* M/λ *open for cross-linguistic variation*. We now explore the possibilities that arise when a given language fixes the relative rankings of the Peak, Margin, and Basic Syllable Structure Constraints. That is, we develop the following theory:

(214) **Basic Segmental Syllable Theory**

• The constraints governing syllable structure are the Peak and Margin association constraints (205, 208), and the syllable structure constraints ONS, −COD, PARSE, and FILL (114−117) and NUC and *COMPLEX (119−120).

• The constraints NUC (119) and *COMPLEX (120) are universally undominated, while the remaining, lower-ranking constraints can be ranked in any domination hierarchy, limited only by universal Syllable Position/Segmental Sonority Prominence Alignment (213).

In other words, we study the Factorial Typology induced by these constraints. Our focus will be on the distribution of various segments across syllable positions. For now we take as given the segment inventory of a language; in §9.1.2 we will show how the theory can address typological variation in the inventories themselves.

In the Basic CV Syllable Structure Theory, the inputs to be parsed were taken to be all possible CV strings $\{C,V\}^+$. Likewise, in the Basic Segmental Syllable Theory, we abstract away from omissions in the lexicon, and consider the set of inputs to be parsed in a language to be the set of all possible strings of our idealized segments *a*, *i*,…, *d*, *t*. We postpone until §9 our discussion of the issue of structure in the lexicon.

In this chapter we show how the theory can elucidate the consequences for universal grammar of alignments such as that of sonority and syllable position prominence; while focusing on the role of sonority in syllable-internal segment distribution, we are of course not blind to the role of other dimensions and constraints. It is for future research to determine the extent to which the methods developed here, or their extensions, can also shed new light on the role of factors other than sonority.

We shall see that from the ranking of constraints in a given language, a series of parameter values can be computed, each of which sets a sonority value that delimits a distributional class of segments. All segments more sonorous than a parameter we call π_{Nuc} are possible nuclei; all those less sonorous than another parameter π_{Ons} are possible onsets. If there are any segments in common, these are ambidextrous: they are both possible nuclei and onsets. The possible codas are those segments less sonorous than a parameter π_{Cod}, which may have a lower, but not a higher, sonority value than π_{Ons}; the set of possible codas in some languages may be a smaller set than the set of possible onsets, but never the reverse.

In addition to establishing particular results such as these, the theoretical development to follow in this chapter has two other goals. First, the methods that will be developed are quite general and can be applied to a variety of other problems. Secondly, the discussion will show how the theory enables a surprisingly rich set of conclusions to be formally extracted from a starting point as simple as the Basic Segmental Syllable Theory (214), which involves only simple universal constraints, simple universal operations such as Alignment, and simple means of generating cross-linguistic variation such as the Factorial Typology.

We will ultimately be concerned to derive the previously mentioned licensing asymmetry between onsets and codas. Until we take up this asymmetry, however, we will ignore codas and focus on the distribution of segments within onsets and nuclei.

8.2 Reconstructing the C and V Classes: Emergent Parameter Setting *via* Constraint Ranking

In this section we introduce most of the formal techniques summarized at the beginning of the chapter, and apply them to the problem of determining the conditions on constraint hierarchies under which a segment may be optimally parsed into onset and nucleus positions. These conditions are assembled in (239) at the beginning of §8.3, in which section they form the basis of our typology of inventories of onsets and nuclei. On a first reading, it may be desirable to skim up to §8.3, as the formal and logical development of §8.2 is rather involved.

8.2.1 Harmonic Completeness of Possible Onsets and Peaks

We begin by observing a direct consequence of the universal Margin and Peak Hierarchies for the role of sonority in the distribution of segments within syllables. The universal Margin Hierarchy says that less sonorous segments make more harmonic onsets; *Harmonic Completeness* implies that if some segment is a possible onset, then so are all less sonorous segments.

(215) **Harmonic Completeness: Possible Onsets and Nuclei**
If $|\lambda| > |\tau|$ and λ is a possible onset, then so is τ. If $|\alpha| > |\lambda|$ and λ is a possible nucleus, then so is α.

The validity of (215) follows from a basic lemma concerning the Harmonic Ordering of Forms:

(216) **Cancellation Lemma**
Suppose two structures S_1 and S_2 both incur the same mark *m. Then to determine whether $S_1 \succ S_2$, we can omit *m from the list of marks of both S_1 and S_2 ('cancel the common mark') and compare S_1 and S_2 solely on the basis of the remaining marks. Applied iteratively, this means we can cancel *all* common marks and assess S_1 and S_2 by comparing only their unshared marks.

This lemma is proved below in the appendix, part of some formal analysis of HOF which we have postponed. That (215) follows from (216) requires a slightly involved argument; a first approximation to the argument runs as follows. By assumption, λ is a possible onset, so there must be some input I containing λ which is assigned an analysis S in which λ is parsed as an onset, i.e., S contains the association Ons/λ (which incurs the mark *M/λ). Replacing this occurrence of λ by τ in I and S produces a new input I′ and a new structure S′; we claim that S′ is the structure assigned to I′, and that therefore τ too is a possible onset.

I:	---λ---	S:	---Ons/λ---
I′:	---τ---	S′:	---Ons/τ---

The central point is that the marks earned by S' are the same as those earned by S, except that a mark $*M/\lambda$ has been replaced by $*M/\tau$; by the Cancellation Lemma, in comparing S and S' we can cancel all their common marks and determine which is more harmonic solely on the basis of their unshared marks, $*M/\lambda$ for S and $*M/\tau$ for S'. Since $|\lambda| > |\tau|$, by (207) $*M/\lambda \gg *M/\tau$ so we conclude that $S' \succ S$. Since S is the output assigned by the grammar to I, it is optimal, that is, more harmonic than all its competitors. Since $S' \succ S$, it is tempting to conclude that S' is therefore also optimal, giving the desired conclusion that S' is the output assigned to I', and that therefore τ is a possible onset. Unfortunately, the fact that S is more harmonic than all its competitors does *not* entail that S' is more harmonic than all *its* competitors: the competitors to S' as analyses of I' *also have λ replaced by τ*, and so they too, like S', can be more harmonic than their λ-counterparts. Here, then, is the actual proof:

Proof of (215): Let I,S and I',S' be as above. Now consider a competitor C' as an output for I'; we must show that $S' \succ C'$. Let C be the corresponding competitor to S (with λ in place of τ).

I:	---λ---	S:	---M/λ---	C:	---$\langle\lambda\rangle$--- or ---P/λ--- or ---M/λ---
I':	---τ---	S':	---M/τ---	C':	---$\langle\tau\rangle$--- or ---P/τ--- or ---M/τ---

As pointed out above, we know that $S' \succ S$ and that $S \succ C$. We would be done if $C \succeq C'$, but this need not be case; it depends on the analysis in C (C') of λ (τ):

Case 1: λ is unparsed in C, i.e. $\langle\lambda\rangle$ in C, and therefore $\langle\tau\rangle$ in C'. In this case, the same mark, *PARSE, is earned by both λ and τ so C and C' incur exactly the same marks: $C \approx C'$. Thus $S' \succ S \succ C \approx C'$ and we are done.

Case 2: λ is parsed as a peak P/λ in C, and therefore τ is parsed as P/τ in C'. Now the difference in marks incurred by C and C' is that C incurs $*P/\lambda$ while C' incurs $*P/\tau$. By the Peak Hierarchy (204), $*P/\tau \gg *P/\lambda$, so $C \succ C'$ and again we are done: $S' \succ S \succ C \succ C'$.

Case 3: λ is parsed as a margin M/λ in C, so τ is parsed as M/τ in C'. Now, since $*M/\lambda \gg *M/\tau$, we have $C' \succ C$, and we are *not* done. Since $*M/\lambda$ is incurred in *both* S and C, however, it cannot be responsible for the fact that $S \succ C$. That is, in comparing the marks incurred by S and by C to determine which is more harmonic, the mark $*M/\lambda$ cancels out of the comparison; the fact that $S \succ C$ must therefore follow from the remaining marks. But these are exactly the same as the marks that remain in the comparison of S' to C', since $*M/\lambda$ has been replaced by $*M/\tau$ in both S' and C', and it cancels in this comparison as well. So just as the marks remaining after cancellation of $*M/\lambda$ determine that $S \succ C$, so these same marks entail after cancellation of $*M/\tau$ that $S' \succ C'$.

An immediate typological consequence of Harmonic Completeness (215) is:

(217) **Possible Onset and Nuclei Parameters**

The cross-linguistic variation in the sets of possible onsets and nuclei are governed by two parameters, π_{Ons} and π_{Nuc}, which are sonority cut points in the Margin and Peak hierarchies. The possible onsets are those segments with sonority less than or equal to π_{Ons}:

$$\text{PossOns} = \{\tau : |\tau| \leq \pi_{Ons}\};$$

the possible peaks are those segments with sonority greater than or equal to π_{Nuc}:

$$\text{PossPeak} = \{\alpha : |\alpha| \geq \pi_{Nuc}\}$$

Exactly characterizing what determines these cut points π_{Ons} and π_{Nuc} is a main goal of the following analysis: these are not primitive parameters directly set in the grammar of a particular language; rather their values are derived consequences of the language's ranking of the universal constraints. (The results are (247) and (248) of §8.3.)

In the sequel it will be convenient to adopt the following:

(218) **Definition of *t* and *a***

In a given language, let *t* denote a segment of minimal sonority and *a* a segment of maximal sonority.

It is clear from (217) that if a language has any possible onsets, then *t* is one; if any possible peaks, then *a*. The reason for the qualification is that the theory as developed so far does not rule out a language in which all onsets or all nuclei are epenthesized. We assume henceforth that in every language, such a possible onset *t* and possible nucleus *a* exist.

8.2.2 Peak- and Margin-Affinity

In the present theory, the most obvious question concerning the relation between individual segments and syllable positions is: for a given segment λ, is the association to Peak, P/λ, or to Margin, M/λ, more harmonic? This question dichotomizes the segment inventory in a particular language:

(219) **Syllable Position Affinity**

If in a given language $P/\lambda \succ M/\lambda$, or equivalently $*M/\lambda \gg *P/\lambda$, then λ is a *peak-preferring* segment; otherwise λ is *margin-preferring*.

The universal Peak and Margin Hierarchies have a sharp consequence for affinity:

(220) **The Affinity Cut Theorem**

Suppose $|\lambda| > |\tau|$. Then if τ is peak-preferring, so is λ. If λ is margin-preferring, so is τ. Thus there is a cut in the sonority scale, above which all segments are peak-preferring and below, margin-preferring. The only parameter of cross-linguistic affinity variation is the sonority level π_{Aff} of this cut point.

To see this, select for concreteness $\lambda = a$ and $\tau = i$. Suppose that in a given language *i* is peak-preferring. Then the following ranking of constraints must hold in the language:

(221) $\text{*M}/a \gg \text{*M}/i \gg \text{*P}/i \gg \text{*P}/a$

The first and last rankings are parts of the universal Margin and Peak Hierarchies, (207) and (204) respectively; the middle ranking $\text{*M}/i \gg \text{*P}/i$ simply asserts our hypothesis that *i* is peak-preferring. Reading off the left and right ends of (221), we see that $\text{*M}/a \gg \text{*P}/a$, i.e., that *a* too is peak-preferring. The situation can be illustrated as follows, the unshaded cells corresponding directly to (221):

(222) **Interleaving of Margin and Peak Hierarchies**

Universal Peak Hierarchy (207)	$\text{*P}/t \gg$	$\cdots \gg$	$\text{*P}/l \gg$		$\text{*P}/i \gg$	$\text{*P}/a$	
Language-Particular				$\gg$			
Universal Margin Hierarchy (204)		$\text{*M}/a \gg$	$\text{*M}/i \gg$		$\text{*M}/l \gg$	$\cdots \gg$	$\text{*M}/t$

This diagram represents the large number of hierarchies gotten by unifying the Margin and Peak Hierarchies into a single hierarchy, in such a way that $\text{*M}/i \gg \text{*P}/i$. The diagram shows immediately that the same relation, $\text{*M}/a \gg \text{*P}/a$ follows, and in general, that $\text{*M}/\iota \gg \text{*P}/\iota$ for one segment ι will entail the same domination relation for any more sonorous segment α: if ι is peak-preferring, so must be α. This means that if ι denotes the least-sonorous peak-preferring segment, the least sonorous segment obeying the property $\text{*M}/\iota \gg \text{*P}/\iota$ displayed by $\iota = i$ in (222), then all segments more sonorous than ι are peak-preferring also, and all less sonorous segments are margin-preferring (else there would be a segment less sonorous than ι which is peak-preferring, contrary to the definition of ι). Thus the 'cut point' π_{Aff} of the Affinity Cut Theorem (220) lies between the sonority level of ι and the next sonority level lower: more sonorous segments (starting with ι) are peak-preferring, less sonorous segments are margin-preferring:

(223) **Affinity Parameter:** π_{Aff} is located as follows between two adjacent sonority levels, that of the most sonorous margin-preferring segment and that of the least sonorous peak-preferring segment:

$$\max_\lambda\{|\lambda| : \text{*P}/\lambda \gg \text{*M}/\lambda\} < \pi_{\text{Aff}} < \min_\iota\{|\iota| : \text{*M}/\iota \gg \text{*P}/\iota\}\ .$$

As with the sonority values for the parameters π_{Ons} and π_{Nuc} introduced above, the sonority value π_{Aff} is not a primitive parameter set directly by a grammar, but rather a value determined by the language's ranking of universal constraints, as illustrated in (222).

8.2.3 Interactions with PARSE

In and of itself, the affinity of a segment does not determine its distribution. In general, there will be conflicts between respecting the segment's affinity and other constraints. The easiest such interaction to analyze involves PARSE.

Suppose *M/α is ranked above PARSE. Then parsing α as a Margin is so low in Harmony as to be even less harmonic than phonetically deleting the entire input string containing α — that is, assigning no structure to it at all (*i.e.*, the Null Parse of §4.3.1). For while assigning no structure incurs many *PARSE marks (one for each segment in the input string), the one mark *M/α that is sure to be incurred in any analysis in which α is parsed as an M is less harmonic than any number of *PARSEs, by the hypothesis that *M/α strictly dominates PARSE. This observation illustrates a useful general technique of analysis:

(224) **Harmonic Bounding**

In order to show that a particular structure φ does not appear in the outputs of a grammar, it suffices to show that any candidate structure A containing φ is less harmonic than *one* competing candidate B (of the same input). (B provides a *harmonic (upper) bound* for A).

Note that the competing candidate B need not be the *most* harmonic one, it need only be *more* harmonic than A, *i.e.* $B \succ A$. In the case at hand, to show the impossibility of the association φ = M/α, we have identified a structure B, the Null Parse, which harmonically bounds any structure containing φ. For the vast majority of inputs, the Null Parse B will not be the *optimal* analysis; but it nonetheless suffices as a harmonic upper bound. (The optimal analysis of an input containing α may, for example, involve failing to parse only α; or it may involve parsing α as a peak.)

Thus a major dichotomy in the segments is induced by the location of PARSE within the Margin Hierarchy of constraints:

(225) **Untenable Associations**

A segment α is defined to be an *untenable margin* iff *M/α ≫ PARSE, i.e., if α is more harmonic deleted ⟨α⟩ than parsed as a margin M/α. τ is an *untenable peak* iff *P/τ ≫ PARSE. If λ is both an untenable peak and an untenable margin, then λ is an *untenable surface segment*. If α is an untenable margin then it is not a possible margin; likewise for peaks.

Note that this result gives us a bit of information about the values of the parameters π_{Ons} and π_{Nuc}. The highest π_{Ons} can possibly be is the highest sonority level $|\tau|$ at which PARSE dominates *M/τ; for higher sonority levels $|\alpha| > |\tau|$, *M/α dominates PARSE and thus α is an untenable margin hence not a possible onset. This situation is illustrated in (226) with τ = *i* (compare (222)):

(226) **Untenable Margins**

	*M/*a* ≫	PARSE ≫	*M/*i* ≫	*M/*l* ≫	··· ≫	*M/*t*
a: untenable margin			→ → → →	π_{Ons} (?) → → → →		

The maximum sonority of possible onsets, π_{Ons}, cannot be higher than the sonority level $|i|$, because *a* is an untenable margin (*M/*a* ≫ PARSE). A corresponding illustration for possible peaks (again, compare (222)) is:

(227) **Untenable Peaks**

*P/*t* ≫	···	*P/*n* ≫	PARSE ≫	*P/*l* ≫	*P/*i* ≫	*P/*a*
t–*n*: untenable peaks				→ → → π_{Nuc} (?) → → →		

While we have shown that *M/α ≫ PARSE entails the impossibility of α associating to M in an output, we have yet to examine the converse, whether PARSE ≫ *M/τ entails that M/τ can sometimes appear in an output. It will turn out that the answer is affirmative if τ is margin-preferring; if τ is peak-preferring, then whether it may associate to M turns out to depend on the ranking of other syllable structure constraints such as ONS and FILL^{Ons}.

Thus, while it has been easy to find a *necessary* condition for τ to be a possible margin (viz., PARSE ≫ *M/τ), finding *sufficient* conditions will be much harder. To find a necessary condition for M/τ to surface in a well-formed structure, it sufficed to find *one* competitor (total phonetic deletion) that must be surpassed. To find a *sufficient* condition requires showing that for *all* universally possible orderings of constraints, there is *some* input in which an analysis containing M/τ is more harmonic than *all* its competing analyses. Establishing such a conclusion is rather involved, and we find it prudent to proceed via a series of incrementally developed results, worthwhile in themselves. The result will be necessary and sufficient conditions for a segment to be a possible onset or nucleus; from these conditions will follow a typology of segmental inventories, with respect to syllable structure distribution, and a universal asymmetry in the licensing of segments in codas and onsets.

8.2.4 Restricting Deletion and Epenthesis

In order to limit the set of candidate analyses we will need to consider, we pause here to establish results restricting the environments where under- and overparsing (a.k.a deletion and epenthesis) is possible. The underparsing result concerns the special case of optimal syllables.

(228) **No Deletion of Tenable Segments in Optimal Syllables**

Suppose τ is a tenable margin and α a tenable peak. Then the structure assigned to /τα/ can involve no underparsing.

For the obvious analysis .τά., while not necessarily optimal, is more harmonic than any analysis involving 〈τ〉 or 〈α〉. Since it represents the universally optimal syllable structure (128), .τά. incurs only the marks {*M/τ, *P/α}, with no marks for syllable structure constraint violations. On the other hand, any structure containing either 〈τ〉 or 〈α〉 will incur at least one mark *PARSE. Now to assume that τ and α are a tenable margin and peak, respectively, is precisely to assume that PARSE ≫ *M/τ and PARSE ≫ *P/α (225); thus any alternative containing them which fails to parse either τ or α is less harmonic than .τά. (In other words, .τά. harmonically bounds (224) the set of all candidates containing either 〈τ〉 or 〈α〉.)

The second result is just the Epenthesis Sites theorem (145) of the CV theory (§6.2.3): it holds in the segmental theory we are now developing as well, in which the families of constraints *M/λ and *P/λ have replaced *M/V (121) and *P/C (122) of the CV theory. The demonstration of (145) proceeded via a series of four propositions. Reexamination of these shows that in Propositions 1 and 2, all the Harmony comparisons involved only *unfilled* syllable positions, and no segments, so no constraints involving segments were relevant to the comparisons; thus exactly the same arguments go through in the present theory. Proposition 3 showed that epenthesis into the environment $.(\square)\acute{\square}\mathrm{C}.$ is impossible because of the more harmonic alternative $.\mathrm{C}\acute{\square}.$ Here, the segment C (now call it λ) is parsed as a coda in the first analysis and as an onset in the second; but since both involve the same constraint *M/λ of the current theory, this common mark cancels, and the original conclusion still stands. (This would not be the case if we were to distinguish two families of constraints, *Ons/λ and *Cod/λ, but the theory we are now developing lumps these into *M/λ.) Finally, the new result of Proposition 4 was the impossibility of $.\mathrm{C}\acute{\square}.\square\mathrm{V}.$, because it is less harmonic than .CV.; again, since $.\tau\acute{\square}.\square\acute{\alpha}.$ and $.\tau\acute{\alpha}.$ both incur the association marks {*M/τ, *P/α}, these cancel, and the argument from the CV theory goes through as before. Thus all the Propositions 1–4 still hold in the present segmental theory, therefore so does the FILL Violation Theorem (possible epenthesis sites), a direct consequence of these four propositions.

8.2.5 Further Necessary Conditions on Possible Onsets and Nuclei

We now proceed to find necessary and sufficient conditions for segments to be possible onsets and nuclei. One set of necessary conditions was given in the earlier analysis of untenable associations (225); in this section we derive the following further necessary conditions:

(229) **Possible Onset Condition:** If τ is a possible onset in a language, then:

[1] *P/τ or ONS $\gg$ *M/τ

and

[2] *P/τ or *M/$\square$ $\gg$ *M/τ

(230) **Possible Peak Condition:** If α is a possible peak in a language, then:

[3] *M/α or *P/$\square$ $\gg$ *P/α

Here we have adopted the notations *M/$\square$ $\equiv$ FILL$^{\mathrm{Ons}}$ and *P/$\square$ $\equiv$ FILL$^{\mathrm{Nuc}}$ in order to explicitly represent the conceptual parallelism between the two FILL constraints and the families of *M/λ and *P/λ constraints. And of course '*P/τ or ONS $\gg$ *M/τ' means '*P/τ $\gg$ *M/τ or ONS $\gg$ *M/τ'.

The virtual isomorphism between the Possible Onset and Possible Peak Conditions is more evident in the following pair of alternative, logically equivalent, formulations:

(231) **Possible Onset Condition, Alternate Version:** The condition '[1] AND [2]' of (229) is equivalent to the condition:

'**either**

[i] τ is margin-preferring (*P/τ $\gg$ *M/τ),

or

[ii] {ONS, *M/$\square$} $\gg$ *M/τ $\gg$ *P/τ '.

If τ is a possible onset, then exactly one of [i] or [ii] must hold.

(232) **Possible Peak Condition, Alternate Version:** Condition [3] of (230) can be rewritten:

‘**either**

[iii] α is peak-preferring ($*M/\alpha \gg *P/\alpha$),

or

[iv] $*P/\Box \gg *P/\alpha \gg *M/\alpha$ ’.

If α is a possible peak, then exactly one of [iii] or [iv] must hold.

The nucleus condition arises from the onset condition by exchanging P and M, and ONS and NUC. However, NUC is universally superordinate, whereas the domination position of ONS may vary; so while ONS must be explicitly mentioned in [ii], NUC need not be mentioned in the corresponding condition [iv].

The results expressed in conditions (231) and (232), and their justifications, can be rendered informally as follows. We start with (232), which is slightly simpler.

In order for α to be a possible nucleus, either [iii] it must be less harmonic to parse α as a margin than as a peak (because α is peak-preferring), or, if α prefers to be a margin [iv], then an unfilled Nuc node that could be created by disassociating α from Nuc and parsing it instead as a margin must generate a mark $*\text{FILL}^{Nuc}$ which is worse than the mark $*P/\alpha$ incurred by parsing α into its disprefered peak position.

The situation in (231) is similar. In order for τ to be a possible onset, either [i] it must be less harmonic to parse τ as a peak than as an onset (because τ is margin-preferring), or, if τ prefers to be a peak [ii], then the marks incurred in either removing the Ons node so vacated (*ONS), or in leaving it in place but unfilled ($*\text{FILL}^{Ons}$) must dominate τ’s inherent preference.

We now make these informal explanations precise. The technique we use runs as follows. Suppose we are given a language in which α can be parsed as a peak. Then there must be some input I containing α whose optimal parse O contains Nuc/α. This means that for any competing parse C of I in which α is not parsed as nucleus, we must have O ≻ C. By choosing C so that it forms a kind of minimal pair with O, we can show that O ≻ C can only hold if the constraint hierarchy in the language meets some domination condition, viz., [3] of (230).

So suppose that α is a possible peak, i.e., that there is some input containing α whose analysis O contains Nuc/α. To generate the competitor C, we simply take O and reassociate α to Ons:

(233) **Marks for Nuc/α and a Competitor with Ons/α**

O:	---$\acute{\alpha}$---		$*P/\alpha$
C:	---$\acute{\Box}.\alpha\acute{\Box}$---	$*P/\Box$, $*M/\alpha$, $*P/\Box$	

The mark $*P/\alpha$ incurred by O is exchanged in C for $\{*P/\Box, *M/\alpha, *P/\Box\}$; all the other marks incurred by O (not involving α) are shared by C and thus cancel (216). Thus in order that O ≻ C, it must be that at least one of the marks $*P/\Box$ or $*M/\alpha$ dominates $*P/\alpha$; this establishes [3] (230).

Now consider onsets. Suppose that τ is a possible onset, i.e., that there is some input I containing τ whose optimal parse O contains Ons/τ. We compare O to two competing parses of I, C_1 and C_2, in which τ associates to Nuc (i.e., $\acute{\tau}$):

(234) **Marks for Ons/τ and Competitors with Nuc/τ:**

O:	---.τά---		*M/τ
C_1:	---.□τ́.□ά---	*M/□, *P/τ, *M/□	
C_2:	---.τ́.ά---	*ONS, *P/τ, *ONS	

Since τ is an onset in O, it must be followed by a Nuc position; in (234) this has been notated ά, with the understanding that α may either be an underlying segment associated to Nuc, or □, in the case the Nuc following τ is unfilled.

The marks incurred by O and its competitors are indicated in (234). O incurs *M/τ; this is traded for *P/τ in C_1 and C_2, along with a pair of *M/□ marks in C_1 and a pair of *ONS marks in C_2; all other marks incurred by O (not involving τ; including those incurred by α) are shared by both C_1 and C_2 and thus cancel. In order that O ≻ C_1, either *P/τ or *M/□ must dominate *M/τ. In order that O ≻ C_2, either *P/τ or *ONS must dominate *M/τ. If O is to be the optimal structure, *both* these conditions must hold. Thus we get (229).

In assuming that the languages under study possess a possible onset *t* and a possible nucleus *a*, we are thus implicitly assuming that (229) holds with τ = *t* and that (230) holds with α = *a*.

8.2.6 Sufficient Conditions on Possible Onsets and Nuclei

Now we move on to the main task, to show that the preceding necessary conditions (225, 229, 230) are indeed *sufficient* for segments to be possible onsets and nuclei:

(235) **Possible Peak Sufficient Condition:** If α is a tenable peak and satisfies [3], then α is a possible peak.

(236) **Possible Onset Sufficient Condition:** If τ is a tenable margin and satisfies both [1] and [2], then τ is a possible onset.

Our strategy will be to show that segments τ meeting the necessary conditions for possible onsets do indeed surface as onsets in /τ*a*/, and that segments α meeting the necessary conditions for possible nuclei surface as such in /*t*α/.

We start with peaks, and consider /*t*α/; we want to show that no matter how a language ranks its constraints, consistent with the strictures of Universal Grammar, the analysis .*t*ά. is optimal. The competitors we must consider have been limited by (228), which rules out all deletions for this input [*t* by assumption is a possible hence tenable onset]; and the possible Epenthesis Sites have been limited by (145). The table (237) below — a *universal tableau* — shows all the remaining competitors and the constraints they violate. ***The ordering of columns does not represent strict domination ranking*** since we are reasoning about universal and not language-particular constraint interactions, and there is no particular ranking of the constraints that we can assume; this means that drawing the relevant conclusions from this universal tableau will require somewhat more involved analysis than is needed in a language-particular tableau in which the columns are ordered by the domination hierarchy in that language. As we examine the universal tableau, we will see that some of the relative positions of the columns have been designed to reflect the domination relations which must hold as a consequence of the hypotheses we have made concerning *t* and α.

(237) **Universal Tableau for /*t*α/:**

/tα/→	ONS	*P/*t*	*M/□	*P/□	*M/α	*M/*t*	*P/α	−COD
a ☞ .tά.						*	*	
b .t́α.	*	*PH			*MH	MH	PH	*
c .t□́α.				*$_3$	*$_3$	[*]	3	*
d .t́.ά.	**$_1$	*$_1$				1	[*]	
e .t́.□ά.	*$_1$	*$_1$	*			1	[*]	
f .t́.α□́.	*$_1$	*$_1$		*$_3$	*$_3$	1	3	
g .□t́.ά.	*	*$_2$	*$_2$			2	[*]	
h .□t́.□ά.		*$_2$	**$_2$			2	[*]	
i .□t́.α□́.		*$_2$	*$_2$	*$_3$	*$_3$	2	3	
j .t□́.ά.	*			*		[*]	[*]	
k .t□́.□ά.			*	*		[*]	[*]	
l .t□́.α□́.				**$_3$	*$_3$	[*]	3	

In constructing this large universal tableau, we have exhaustively listed alternatives, rather than following our customary practice with language-particular tableaux of omitting many of the least harmonic candidates. This for the simple reason that here it is not at all clear which *are* the least harmonic candidates, since we are not reasoning about a specific language-particular hierarchy.

So our first task is to verify that the candidates [a-l] are indeed the only ones we need consider. Since legal epenthesis sites (145) all involve either a filled onset or a filled nucleus, with only two underlying segments in /tα/, analyses with more than two syllables must involve illegal epenthesis. Given that deletion is impossible for this input (228), the only possible monosyllabic parses are those shown in rows [a-c]. Given the constrained epenthesis sites, disyllabic parses are limited to those in which the first syllable contains *t* and the second contains α. There are three possible monosyllables containing *t*, given the impossibility of epenthesis into coda position: *.t́.*, .□*t́*., and *.t*□́. These three possibilities are represented in candidates [d-f], [g-i], and [j-l], respectively. There are also the corresponding three possible monosyllables containing α, and the nine bisyllabic parses [d-l] comprise all combinations—the Cartesian product—of the three *t* parses with the three α parses: [d-l] = {*.t́.*, .□*t́*., *.t*□́.} × {.ά., .□ά., .α□́.}. (Actually, one of these bisyllabic candidates [k] involves two adjacent epentheses, already ruled out as legal epenthesis sites (145); we have included [k] in order to exhibit the Cartesian product structure of the bisyllabic candidate set.)

One of these candidates has already been implicitly compared to *.tά.* in the process of deriving the Possible Peak Condition [3] which, by hypothesis, holds of α. The condition [3] was derived as necessary to ensure that a parse ---ά--- is more Harmonic than the alternative ---□́.α□́--- (233). A special case of this comparison is that of [a] to [l]. Thus [3] by construction entails (as we shortly verify) that [a] ≻ [l].

Similarly, since *t* is assumed to be a possible onset, it must meet the conditions [1] and [2] necessary of all possible onsets. So the Harmony comparisons used to derive [1] and [2] have also implicitly been assumed to favor parsing *t* as an onset. Those comparisons were of ---.*t*--- to ---.□*t́*.□--- and to ---.*t́*.---. Thus since *t* satisfies [1] and [2], it will follow that [a] is more harmonic than [h] and [d].

Unfortunately this still leaves eight competitors left to check, and we must resort to examination of the table of marks. It will only be necessary to discuss a few of the cases. The procedure illustrates a general technique, the *Method of Universal Tableaux*, which is useful in other applications. This method relies on the following lemma concerning HOF, derived below in the appendix:

(238) **Cancellation/Domination Lemma**

Suppose two parses B and C do not incur identical sets of marks. Then B ≻ C if and only if every mark incurred by B which is not cancelled by a mark of C is dominated by an uncancelled mark of C.

For the case at hand, this idea should be intuitively clear. We want to show that B = [a] is more harmonic than each of the competitors C in the set [b-l]. [a] incurs two marks, *M/*t* and *P/α. If a competitor C's marks include neither of [a]'s, then in order to show that [a] is more harmonic than C, we must show that each of [a]'s marks is dominated by one of C's marks: this is both necessary and sufficient for showing that among the marks of [a] and C, the worst mark is incurred by C, and that therefore [a] is more harmonic. If one of [a]'s marks is shared by C, we can exploit the Cancellation Lemma and cancel this shared mark from both [a] and C, and then show that the remaining mark of [a] is dominated by a remaining mark of C. If both of [a]'s marks are shared by C, then both cancel, and if C has any other marks at all, it is less harmonic than [a].

In other words, what we need to show is that for any competitor C, the mark *M/*t* of [a] is either *cancelled* by the same mark in C or *dominated* by other uncancelled marks of C; and similarly for [a]'s second mark *P/α. Pursuant to this strategy, the Universal Tableau (237) is annotated according to the method for handling each of [a]'s two marks. In the *M/*t* column for a given competitor C is an annotation indicating whether this mark of [a] is cancelled or dominated by a mark of C. We will have demonstrated that [a] is optimal if we can place an appropriate annotation in both the *M/t and *P/α columns of every competitor.

The annotation scheme is as follows. If [a]'s mark *M/*t* is *cancelled*, then it must be shared by C, so a * must occur in the *M/*t* column of C; we enclose this in brackets [*] to indicate that this mark cancels its counterpart in [a]. If the mark *M/*t* of [a] is *dominated* by a mark of C, then the *M/*t* column of C is annotated with the label of a previously established constraint domination condition which demonstrates this domination; in this case, the particular mark(s) of C which dominate *M/*t* are annotated with the same label. The labels are: 'MH', Margin Hierarchy (207); 'PH', Peak Hierarchy (204), and '1', '2', '3' for conditions [1], [2], and [3] of (229) and (230). MH and PH hold universally; by hypothesis, [1] and [2] hold of $\tau = t$ and [3] holds of α.

So consider the first competitor, [b]. The table indicates that *M/*t* is dominated by *M/α in virtue of the Margin Hierarchy; this is the case assuming that $|\alpha| > |t|$, which will hold in general since *t* is of minimal sonority. (That is, *t* makes a more harmonic onset than α.) The only exception will be if α also is of minimal sonority (e.g., if $\alpha = t$), in which case the two marks *M/*t* and *M/α are of equal domination rank and therefore cancel. The table also indicates that *P/α is dominated by *P/*t* in virtue of the Peak Hierarchy; the same sonority argument applies. (That is, α makes a more harmonic peak than *t*.) Thus the marks of [a] are dominated by those of [b], unless α happens to be of minimum sonority, in which case both of [a]'s marks are cancelled, which still leaves [b] with the two uncancelled marks *ONS and *−COD. (That is, even if α is of the same minimal sonority as *t*, the syllable structure of [a] is more harmonic than that of [b].) So for any α, [a] $\succ$ [b].

In the second competitor, [c], *t* is parsed as an onset, as in [a], so [a]'s first mark *M/*t* is cancelled by [c]. [a]'s second mark *P/α is not cancelled, since α is not parsed as a peak in [c]; however, condition [3] of (230) ensures that *P/α is dominated by either *M/α or by *P/□, and these two marks are both incurred by [c]. Therefore the assumption that the constraint hierarchy of the language satisfies [3] for segment α ensures that [a] $\succ$ [c]. The situation is annotated in row [c] of the universal tableau by putting '3' under *M/α and next to the two marks *P/□ and *M/α of [c] which together ensure by [3] that *M/α is dominated.

We can now revisit the issue of the ordering of the columns in the universal tableau. Consider the annotations in row [b]. The Peak Hierarchy ensures that *P/*t* dominates *P/α, which is suggested by placing the column *P/*t* to the left of the column *P/α. (Unless $|\alpha| = |t|$, in which case these columns are really the same.) Similarly for the Margin Hierarchy and the columns for *M/α and *M/*t*. Note however that there is no reason at all to assume that *P/*t* dominates *M/α; the relative ordering of this pair of columns is not significant. Now consider the annotations in row [c]. Condition [3] says that *either* *P/□ *or* *M/α dominates *P/α, so that if the columns were ordered for a given language to reflect constraint domination, *at least one* of the columns for the constraints *P/□ or *M/α would be left of the column for *P/α; but universally we have no right to assume that *both* are. Thus the placement in the universal tableau of both *P/□ and *M/α left of *M/α must be given this appropriate disjunctive interpretation. And of course, there is no universal significance at all to the relative ordering of the columns *P/□ and *M/α with respect to each other nor to all the other columns left of *M/*t*. In effect, the annotations indicate that *M/*t* and *P/α are dominated in every language by certain of the columns to their left, but beyond that, the order of columns cannot be given a more definite universal interpretation. It is really the constraint domination conditions indicated by the annotations rather than the ordering of the columns in the universal tableau which is critical to assessing the relative harmonies of [a] and its competitors.

We return to the tableau now to consider the remaining, bisyllabic, competitors. Consider [d] = .*t́*.$\acute{\alpha}$., for example. Since both [d] and [a] parse α as a peak, their common marks *P/α cancel. The other mark of [a], *M/*t,* is, according to [1], dominated either by ONS or by *P/t; since both marks *ONS and *P/*t* are incurred by [d], [1] guarantees that *M/*t* is dominated. Thus we have annotated the *M/*t* column of [d] with '1', and used '1' to annotate the relevant pair of [d]'s dominating marks, *ONS and *P/*t*. We have ordered ONS and *P/*t* left of *M/*t* as a mnemonic for [1], which says that one—but not necessarily both—of these constraints must dominate *M/*t*. Note that the second *ONS is not appealed to in this argument; in general, a second mark in any column of the table is not required to demonstrate the greater Harmony of [a]. Neither is any mark *−COD (which appears at the far right since no domination condition ranks it higher than *M/*t* or *P/α).

By tracing the role of [1] in showing that [a] ≻ [d], we have verified a claim made a few paragraphs earlier, that the argument we originally used to derive [1] entails [a] ≻ [d] as a special case. The reasoning just followed, however, extends also to cases [e] and [f], for which the earlier argument does not directly apply. As with [d], in [e] the mark *P/α is cancelled and the mark *M/*t* dominated by virtue of [1]; in [f], *M/*t* is also dominated via [1], but now *P/α no longer cancels. Instead, it too is dominated, in virtue of [3], which says that *P/*t* is dominated by either *P/□ or *M/α.

The Cartesian product structure of the bisyllabic competitor set [d-l], namely

{.*t́*., .□*t́*., .*t* □́.} × {.ά., .□ά., .α□́.}

is directly manifest in the *M/*t* and *P/α columns for these candidates. The mark *M/*t* incurred by *t* in [a] is dominated via [1] for .*t́*., and via [2] for .□*t́*.; it is cancelled for .*t*□́., which like [a] parses *t* as a margin. [a]'s other mark *P/α incurred by α is cancelled for both .ά. and .□ά., both of which parse α as a peak; *P/α is dominated by [3] in .α□́. These dominations via the conditions [1], [2], and [3] are hardly surprising; as already discussed, these three conditions were derived precisely to ensure just these dominations. What the table and all the arguments behind it show, however, is a conclusion that is new and non-obvious: that these domination conditions — together with the universal Margin and Peak Hierarchies, and the assumption that *t* and α are respectively a tenable margin and peak, therefore not deletable in /*t*α/ (228) — are also *sufficient* to prove that α is a possible onset. We have thus proved (235).

The proof of (236) proceeds analogously. To show that in a language in which τ satisfies the domination conditions [1] and [2], τ can appear as an onset, we apply the same technique to prove that .τ*á*. is the optimal analysis of the input /τ*a*/. In fact, the same argument goes through exactly as before, with τ replacing *t* and *a* replacing α. This is because the properties [1] and [2] which we now hypothesize to hold of τ were in the proof of (235) required to hold of *t*, which is by assumption a possible onset; similarly, the possible peak *a* must satisfy the same property [3] that was hypothesized to hold of α in the proof of (235).

8.3 The Typology of Onset, Nucleus, and Coda Inventories

In this section we first derive from the results of §8.2 a typology of onset and peak inventories (§8.3.1), showing explicitly how to extract from the constraint domination hierarchy of a language the values in that language for the parameters π_{Ons} and π_{Nuc} which determine these inventories. We then obtain the corresponding results for codas, and derive an onset/coda licensing asymmetry (§8.3.2). We close the section by returning to Berber to exemplify the results for an actual language (§8.3.3).

8.3.1 The Typology of Onset and Nucleus Inventories

Putting together the results (225, 229−232, 235−236) of the preceding sections, we have the following:

(239) **Typology of Possible Onsets and Peaks**

For τ to be a possible onset, it is necessary and sufficient that

either

[i] {PARSE, *P/τ} ≫ *M/τ (τ a *willing onset*)

or

[ii] {PARSE, ONS, *M/□} ≫ *M/τ ≫ *P/τ (τ a *coercible onset*).

For α to be a possible peak, it is necessary and sufficient that

either

[iii] {PARSE, *M/α} ≫ *P/α (α a *willing peak*)

or

[iv] {PARSE, *P/□} ≫ *P/α ≫ *M/α (α a *coercible peak*).

The onset conditions [i, ii] are the same as those in (231), except that PARSE has been included explicitly to capture the requirement that τ be a tenable peak (225). Similarly for [iii, iv] and (232).

In (239) we have distinguished the possible onsets satisfying each of the mutually exclusive conditions [i] and those [ii], calling the former *willing* and the latter *coercible*; willing onsets are margin-preferring tenable margins, while coercible onsets are peak-preferring tenable margins which can be coerced to override their affinity by higher-ranking syllable-structure constraints, ONS and *M/□ = $\text{F}{\small ILL}^{Ons}$. And analogously for peaks.

We can draw many conclusions from (239). The first concerns affinity (219):

(240) **Affinity and Possibility.** Suppose λ is a tenable surface segment. Then if λ is margin-preferring, it is a possible onset; if peak-preferring, a possible peak.

This conclusion follows immediately from (239): if λ is margin-preferring, then by definition M/λ ≻ P/λ, i.e., *P/λ ≫ *M/λ; if λ is a tenable surface segment, then PARSE must dominate either *P/λ or *M/λ, i.e., PARSE must dominate the lowest constraint, *M/λ. This establishes [i], so λ is a possible (indeed a willing) onset. And correspondingly if λ is peak-preferring.

Using (239) the segmental inventory in a given language can now be divided into a number of overlapping classes. These are illustrated in the following table, for the case of a language with ambidextrous segments. The horizontal axis is the sonority scale, increasing to the right:

(241) **Segmental Classes (with Ambidextrous Segments)**

		Increasing Sonority →		
t	π_{Nuc}	π_{Aff}	π_{Ons}	*a*
←	willing onsets	→←	willing peaks	→
	← coercible peaks	→←	coercible onsets →	
←	possible onsets		→	
	←	possible peaks		→
← pure onsets	→←	ambidextrous segments	→← pure peaks	→

This analysis of the segment classes is a direct logical consequence of (239). The reasoning depends on the following results:

(242) **Segment Classes**

a. A coercible onset is a willing peak; a coercible peak is a willing onset.

b. The set of *ambidextrous segments*, those which are both possible onsets and possible peaks, is the set of coercible segments. Each ambidextrous segment λ satisfies

PARSE $\gg$ {*M/λ, *P/λ}.

c. The set of *impossible surface segments*, those which are neither possible onsets nor possible peaks, is the set of untenable surface segments (225), i.e., those λ for which

{*M/λ, *P/λ} $\gg$ PARSE.

d. The set of possible onsets, $\{ \lambda : |\lambda| \le \pi_{Ons}\}$, is the union of the sets of willing and coercible onsets.

e. The set of possible peaks, $\{ \lambda : |\lambda| \ge \pi_{Nuc}\}$, is the union of the sets of willing and coercible peaks.

f. The set of *pure onsets*, those segments which are possible onsets but not possible peaks, is the set of willing onsets minus the set of coercible peaks.

g. The set of *pure peaks*, those segments which are possible peaks but not possible onsets, is the set of willing peaks minus the set of coercible onsets.

These observations are all immediate consequences of (239) and (217).

For example, (242a) follows from (239) since a coercible onset is a segment λ which satisfies [ii] with $\tau = \lambda$, which includes the requirement that

$$\textsc{Parse} \gg {*}M/\lambda \gg {*}P/\lambda;$$

then necessarily [iii] holds with $\alpha = \lambda$, so λ is also a willing peak. The second part of (242a) follows by exactly analogous reasoning.

Then the first part of (242.b) follows immediately, since (242.a) entails that all coercible segments are ambidextrous (and no segment can be ambidextrous unless it is coercible). The second part of (242.b) follows since, from [ii] and [iv] we see that, among other things, a coercible segment λ must satisfy

$$\textsc{Parse} \gg \{{*}M/\lambda, {*}P/\lambda\}.$$

The argument for (242.c) is slightly more involved. Suppose λ is an impossible surface segment. Like any segment, λ is either peak-preferring or margin-preferring. Suppose the former:

($\aleph$) $\quad {*}M/\lambda \gg {*}P/\lambda.$

Then if we had

$$\textsc{Parse} \gg {*}P/\lambda,$$

λ would be a willing peak; so, since λ is an impossible surface segment, we must have instead

$${*}P/\lambda \gg \textsc{Parse}.$$

Thus, given ($\aleph$), we must have

$$\{{*}M/\lambda, {*}P/\lambda\} \gg \textsc{Parse},$$

the desired conclusion. If instead λ is margin-preferring, the same conclusion follows by exchanging M and P in the argument.

The remaining points (242.d–g) are obvious, given (242.a), and serve only to introduce terminology and reintroduce the parameters π_{Ons} and π_{Nuc} from (217).

The diagram (241) above illustrates a language possessing ambidextrous segments but no impossible surface segments. It turns out that:

(243) No language can have both ambidextrous and impossible surface segments.

To show this, we derive a contradiction from supposing that a single language has an impossible surface segment λ and an ambidextrous segment α. From (242.b), α must satisfy

$$\textsc{Parse} \gg \{{*}M/\alpha, {*}P/\alpha\}.$$

From (242.c), λ must satisfy the opposite domination,

$$\{{*}M/\lambda, {*}P/\lambda\} \gg \textsc{Parse}.$$

Combining these, we get:

$$\{{*}M/\lambda, {*}P/\lambda\} \gg \textsc{Parse} \gg \{{*}M/\alpha, {*}P/\alpha\}$$

But this contradicts the Peak and Margin Hierarchies (204, 207). For by the Margin Hierarchy,

$${*}M/\lambda \gg {*}M/\alpha \text{ entails } |\lambda| > |\alpha|$$

while by the Peak Hierarchy,

$${*}P/\lambda \gg {*}P/\alpha \text{ entails } |\lambda| < |\alpha|.$$

Diagram (243) asserts that languages divide into those with ambidextrous segments, those with impossible surface segments, and those with neither. The diagram corresponding to (241) for a language with impossible surface segments is simpler:

(244) **Segmental Classes (with Impossible Surface Segments)**

Increasing Sonority →

t	π_{Ons}	π_{Aff}	π_{Nuc}	a
← willing onsets →			← willing peaks →	
← possible onsets →			← possible peaks →	
← pure onsets →	← impossible surface segments →		← pure peaks →	

In the context of the current Basic Segmental Theory, it is unclear what role could be played in such a language by the impossible surface segments. There seems to be no way to distinguish the case in which such a segment is present in a morpheme — and necessarily left unparsed regardless of what other segments the morpheme may combine with in an input — and the case in which such a segment is simply not present underlyingly, and indeed not part of the segmental inventory of the language. Thus it would appear that there is no need to postulate underlying segments at sonority levels which correspond to impossible surface segments (and indeed the acquisition theory introduced in §9.3 will entail that learners would not posit underlying forms containing such segments). *Henceforth, we will restrict attention to languages without such impossible surface segments.* In theories richer than the Basic Segmental Theory (214), impossible surface segments could of course function in a language: there would need to be additional constraints which are sensitive to such segments even though they are not parsed into syllable structure and not phonetically realized.[67]

Our assumption that the languages under study are all without impossible surface segments has the following consequence:

(א) PARSE $\gg$ *M/τ when τ is margin-preferring.

For if not,

(ב) *M/τ $\gg$ PARSE

[67] Such a situation was, in a sense, illustrated in our analysis of Lardil (§7), where the FREE-V constraint asserted that word-final vowels must not be parsed; parsed vowels which are surface-final but followed by unparsed underlying segments do **not** violate this constraint. Thus /*wuŋkunuŋ*/ [‘queen-fish’, §7.1 (150.a)] surfaces as [*wuŋkunu*] parsed as *.wuŋ.ku.nu*〈*ŋ*〉.; the final underlying segment *ŋ* functions in the language via FREE-V to allow the parsing of the last *u*. The unparsed segment is of course, however, not an impossible type of surface segment; even that particular token of ŋ in fact surfaces in other inflections of the same stem.

and since τ is margin-preferring,

$$*\mathrm{P}/\tau \gg *\mathrm{M}/\tau,$$

and hence

$$\{*\mathrm{P}/\tau, *\mathrm{M}/\tau\} \gg \textsc{Parse}.$$

Then τ is an untenable surface segment and by (242.c), τ is an impossible surface segment. This contradicts our assumption on the language so (ב) must be incorrect and (א) correct. By exchanging margin and peak, the same argument shows that

(ג) PARSE $\gg$ *P/α if α is peak-preferring.

Now (א) entails that [i] of (239) holds, so a margin-preferring segment τ is a possible onset. Similarly, (ג) implies [iii] of (239), so a peak-preferring segments α is a possible onset. Thus:

(245) In a language without impossible surface segments, all margin-preferring segments are possible (hence willing) onsets, and all peak-preferring segments are possible (hence willing) peaks.

This situation is illustrated in (241): recall that the margin-preferring segments are those left of (less sonorous than) π_{Aff}, and the peak-preferring segments are those right of (more sonorous than) π_{Aff}, as seen in (220) and (223).

Using (239) we can now derive explicit expressions for the parameters π_{Ons} and π_{Nuc} which govern the segment classes of (241) and (242). First, define:

(246) **Critical Constraints:** $C_{\mathrm{Ons}} \equiv \min\{\textsc{Parse}, \textsc{Ons}, *\mathrm{M}/\square\}$; $C_{\mathrm{Nuc}} \equiv \min\{\textsc{Parse}, *\mathrm{P}/\square\}$

That is, in a particular language, C_{Ons} names the least dominant of the three constraints PARSE, ONS and *M/$\square$ = FILL$^{\mathrm{Ons}}$. This is the constraint which, according to (239.ii), determines which peak-preferring segments λ are coercible onsets: they are the ones for which $C_{\mathrm{Ons}} \gg *\mathrm{M}/\lambda$. π_{Ons} is by definition (217) the highest sonority level at which this condition holds. Thus we have:

(247) **Onset Inventory Parameter Value:** $\pi_{\mathrm{Ons}} = \max_{\lambda}\{\ |\lambda| : C_{\mathrm{Ons}} \gg *\mathrm{M}/\lambda\}$

That is, the value of the parameter π_{Ons} in a given language is the sonority value of the most sonorous segment λ for which *M/λ is dominated by C_{Ons}. For segments α more sonorous than this, parsing the segment as an onset incurs a worse mark (*M/α) than the mark (*PARSE, or *ONS, or *M/$\square$) which would be incurred by some alternative in which α is not parsed as an onset (as the analysis of §8.2 has shown.)

By exactly analogous reasoning,

(248) **Nucleus Inventory Parameter Value:** $\pi_{\mathrm{Nuc}} = \min_{\lambda}\{\ |\lambda| : C_{\mathrm{Nuc}} \gg *\mathrm{P}/\lambda\}$

That is, π_{Nuc} is the sonority value of the least sonorous segment λ for which *P/λ is dominated by C_{Nuc}.

We can illustrate how the ordering of constraints in a particular hypothetical language sets these parameters by showing how to go from (222) to (241) via (223), (247), and (248). (In §8.3.3 we consider an actual language, Berber.)

(249) **Deriving Segmental Class Parameters π_{Nuc} and π_{Ons}: An Example.**

Decreasing Constraint Dominance →

a.			*f* ←	Possible Nuclei			→ *a*
b.			π_{Nuc}				
c.		$\mathbf{C_{Nuc}}$=	=|*f*|			|*l*|< π_{Aff} <|*i*|	
d. **PARSE**		***P/□**					
e. ***P/*t***	***P/*d***		***P/*f***	…		***P/*l***	***P/*i*** ***P/*a***
f.						≫	
g.			***M/*a***		***M/*i***	***M/*l*** …	***M/*d*** ***M/*t***
h. **PARSE *M/□**				**ONS**			
i.				=$\mathbf{C_{Ons}}$	|*i*|=		
j.					π_{Ons}		
k.					*i* ←	Possible Onsets	→ *t*

In (249), constraints are indicated in boldface in rows c–i, between the solid lines. They are arranged, as usual, with the most dominant constraints to the left. (Note that, unlike (241), the horizontal axis shows constraint domination and not sonority.) This is an example of a particular language, so the constraints form a strict domination hierarchy. For clarity, we have vertically separated the constraints into the rows c–i, but they are nonetheless strictly ranked left-to-right. Rows e–g are a copy of (222); we have suppressed the explicit domination symbols '≫' except in row f, which shows the cross-over point in the domination hierarchy (as in diagram (222)). To the left of this point are the constraints *P/τ which dominate their counterparts *M/τ; these are the margin-preferring segments. In the example illustrated here, this cross-over point occurs between the sonority levels |*l*| of the most sonorous margin-preferring segments, and |*i*| of the least sonorous peak-preferring segments. As indicated in line c, this cross-over point on the sonority scale is the affinity parameter π_{Aff} (223).

To determine the sonority values of the other two parameters π_{Nuc} (248) and π_{Ons} (247), we need first to identify the critical constraints C_{Nuc} and C_{Ons} (246). The constraints relevant to identifying C_{Nuc} are shown on line d; the least dominant one in this example is *P/□, which has therefore been identified in line c as C_{Nuc}. According to (248), the value of π_{Nuc} is the lowest sonority value $|\lambda|$ of those segments λ for which $C_{Nuc} \gg$ *P/λ; this value is $|f|$ here, so lines b–c indicate that in this language $\pi_{Nuc} = |f|$. That is, all segments at least as sonorous as *f* are possible nuclei (217); this is noted in line a.

Analogously, the constraints relevant to determining C_{Ons} are shown in line h (one of them, PARSE, was also shown in line d). The lowest ranking is C_{Ons} = ONS, as noted in line i. Then (247) tells us that the value of π_{Ons} is the sonority value $|\lambda|$ of the most sonorous segment λ for which $C_{Ons} \gg$ *M/λ; in this example, this value is $|i|$, as noted in lines i–j. That is, as noted in line k, all segments at most as sonorous as *i* are possible onsets (217).

Note that for reading off the possible nuclei, we consult the constraints *P/λ, which are arrayed in order of *increasing* sonority (line e), following the Peak Hierarchy (204), while for identifying the possible onsets, we examine the constraints *M/λ, arrayed with *decreasing* sonority (line g), as demanded by the Margin Hierarchy (207). Hence the opposite segment ordering indicated in lines a and k.

In this example, the ambidextrous segments are those λ with sonority values at least $|f|$ and at most $|i|$; these are segments for which *P/λ finds itself to the right of C_{Nuc} *and* *M/λ falls to the right of C_{Ons}. The set of ambidextrous segments is not directly evident in the diagram (249), but rather inferred as the intersection of the nucleus inventory displayed in line a and the onset inventory identified in line k.

8.3.2 Onset/Coda Licensing Asymmetries

In this section, we derive necessary and sufficient conditions for a segment to be a possible coda. The analysis takes the form of a high-speed recapitulation of the methods applied earlier to onsets and nuclei. Once the conditions for possible codas are in hand, we can extract the typological consequences, including a licensing asymmetry.

In order for a language to permit any codas at all, we must have

(250) **Codas Allowed:** {PARSE, *P/□} $\gg$ −COD

as in the Coda Theorem (138), p.102, of CV Theory. We will rederive this condition for the present Segmental Theory in the course of establishing the following result:

(251) **Necessary Condition for Possible Codas.** If τ is a possible coda, then it must meet conditions [i] or [ii] for possible onsets (239). *In addition,* **either**

[v] {ONS, *M/□} $\gg$ −COD

or

[vi] *P/τ $\gg$ −COD

must hold as well.

To see this, consider any input containing τ the optimal parse of which is a structure O in which τ is parsed as a coda. Such a structure can be represented ---$\acute{\alpha}\tau$.--- since a coda is necessarily preceded by an nucleus. (Any unparsed segments that may intervene between α and τ can be ignored.) This structure O must be more harmonic than all its competitors, including the four shown below:

(252) **Marks for Cod/τ and Competitors:**

S:	---ά τ.---	*–COD, *M/τ
C_1:	---ά⟨τ⟩.---	*PARSE
C_2:	---ά.τ□́.---	*M/τ, *P/□
C_3:	---ά.τ́.---	*ONS, *P/τ
C_4:	---ά.□τ́.---	*M/□, *P/τ

Each competitor C_i is identical to the parse O except in how τ is parsed. As in the corresponding analyses for nuclei (233) and onsets (234), we have ignored in (252) all the marks incurred by O and C_1–C_4 except those directly incurred by τ, since these other marks all cancel in comparing S to each competitor (216).

According to the Cancellation/Domination Lemma, (192) and (238), if O is to be optimal, each of O's two marks *–COD and *M/τ must be cancelled or dominated by the marks incurred by each of these competitors. Thus, considering C_1, since *M/τ is not cancelled, it must be dominated:

(א) PARSE ≫ *M/τ

i.e., τ must be a tenable margin. Also *–COD must be dominated, so we must have

(ב) PARSE ≫ –COD,

as claimed above in (250). Considering next C_2, since the marks *M/τ cancel, we deduce that O's mark *–COD must be dominated by C_2's remaining mark:

(ג) *P/□ ≫ –COD.

(ב) and (ג) rederive (250).

Next we consider the competitors C_3 and C_4, which cancel neither of O's marks. In order for O's mark *M/τ to be cancelled in these two cases, we must have, for C_3:

(ד) *P/τ ≫ *M/τ **or** ONS ≫ *M/τ

and, for C_4:

(ה) *P/τ ≫ *M/τ **or** *M/□ ≫ *M/τ

In other words, (including PARSE from (א)) **either**:

[i] {PARSE, *P/τ} ≫ *M/τ

(in which case the common left half of (ד) and (ה) holds), **or**

[ii] {PARSE, ONS, *M/□} ≫ *M/τ

(in which case the right halves of (ד) and (ה) hold). These necessary conditions [i, ii] for a possible coda are identical to the conditions for a possible onset (239). So we have established the first part of the Necessary Condition for Possible Codas (251).

But O incurs another mark, *–COD, which also must be dominated in C_3 and C_4. The conditions are the same as for *M/τ, which is now simply replaced by *–COD: 'either [i] or [ii]' becomes (omitting PARSE now, since it is already covered by (250)) '**either**

[vi] *P/τ ≫ –COD

or

[v] {ONS, *M/□} ≫ –COD.'

Condition [v] does not refer to the segment τ; it is a condition on the ranking of the Basic Syllable Structure Constraints in the domination hierarchy of a language which may or may not be satisfied. It is completely independent of the condition (250) which admits codas into the language. It says that the language's aversion to codas (–COD) is less strong than its aversion to onsetless syllables (ONS) and unfilled margins (*M/□):

(253) A language satisfying (251.[v]):
{ONS, *M/□} ≫ –COD
is said to be **weakly coda averse.**

In languages which are *not* weakly coda averse, the segment-specific condition [vi] must hold of τ for it to be a possible coda. In weakly coda averse languages, on the other hand, the Necessary Condition for Possible Codas (251) reduces to just the condition for possible onsets.

This establishes (251). The idea at the core of this argument is very simple: associating a segment τ to a Cod node incurs the same mark *M/τ as associating it to an Ons node, and *in addition* the mark *–COD. The asymmetry in the Basic Syllable Structure Constraints between the Ons (114) and Cod (115) nodes entails that the Cod association is inherently more marked than the Ons association. Therefore additional domination conditions must be met for the association Cod/τ to be optimal, above and beyond those conditions necessary for Ons/τ to be optimal. These additional conditions can, as we will soon see, exclude certain possible onsets from the coda inventory, in languages where the mark *–COD is sufficiently dominant, i.e., in languages which are not weakly coda averse.

An immediate corollary of (251) is:

(254) **Possible Coda ⇒ Possible Onset.** If τ is a possible coda, then it is a possible onset.

Next we show:

(255) **Sufficient Conditions for Possible Codas.** The conditions of (251) are sufficient for τ to be a possible coda (in a language permitting codas).

To see this, consider the input /*ta*τ/; we show that the conditions of (251) entail that the optimal analysis is .*tá*τ., in which τ is parsed as a coda. This conclusion follows from the following lemma:

(256) **Lemma:** The initial substring /*ta*/ of /*ta*---/ is parsed as .*tá*···.

Proof: *.tá.* is an optimal syllable (128) which violates no Basic Syllable Structure Constraints; its only marks are the associational ones *M/*t* and *P/*a*. The presence of the following '---' in the input does not afford opportunities to eliminate any syllable structure constraint violations in *.tá.*, since there aren't any; alternative parses can only introduce new such violations, while possibly trading the marks *M/*t* and *P/*a* for alternative associational marks (if *t* and *a* are reassigned to different syllable positions). But we already know that all of these alternatives generate marks which dominate those of *.tá.*, for this was established by the argument based on the universal tableau (237). This investigation of /*tα*/ showed that, assuming *t* to be a possible onset and α to be a possible nucleus, the marks incurred by *.tά.* are dominated by those incurred by all its competitors. Thus if we reiterated all those competitors, with α = *a*, combining them in all possible ways with the possible analyses of '---', to form the universal tableau for /*ta*---/, we would simply end up showing that the marks incurred by *t* and *a* in any structure of the form *.tá···.* are dominated by the marks they incur in any of the competing analyses that parse the initial substring /*ta*/ differently.

From this lemma we see that the only competitors to the analyis O = *.tá*τ. that we need consider are those of the form *.tá···*, with '···' denoting all possible parses of τ. But this is exactly the set of competitors considered in (252), where the pre-τ segment denoted '---ά' in (252) is taken to be '*.tá*' and the post-τ segment denoted '---' in (252) is taken to be empty. The necessary conditions of (251) were just those needed to ensure that O was indeed more harmonic than its four competitors in (252). Thus these necessary conditions are also sufficient.

The Necessary (251) and Sufficient (255) Conditions for Possible Codas entail:

(257) **Possible Coda Parameter.** The possible codas are those segments with sonority value less than or equal to a cut-off parameter π_{Cod}:

$$\text{PossCod} = \{\ \tau : |\tau| \le \pi_{\text{Cod}}\}.$$

In a weakly coda averse language, the value of π_{Cod} is given by:

$$\pi_{\text{Cod}} = \pi_{\text{Ons}};$$

otherwise,

$$\pi_{\text{Cod}} = \min\{\pi_{\text{Ons}}, \max_{\lambda}\{|\lambda| : {}^{*}\text{P}/\lambda \gg -\text{C}\textsc{od}\}\ \}.$$

For (251) says that if [v] holds, then the conditions on a possible coda are exactly the same as on a possible onset, so PossCod = PossOns, and the parameters characterizing the two segmental classes have the same value. So assume the language is not weakly coda averse, i.e., that [v] does not hold. Then a possible coda τ must be a possible onset, but in addition, [vi] must hold:

[vi] $\quad {}^{*}\text{P}/\tau \gg -\text{C}\textsc{od}.$

Note that if this condition [vi] is satisfied for any segment τ, it is also satisfied by any less sonorous segment λ, for the Peak Hierarchy (204) ensures that

$${}^{*}\text{P}/\lambda \gg {}^{*}\text{P}/\tau \gg -\text{C}\textsc{od}.$$

Thus in order for τ to be a possible coda, its sonority value |τ| must be less than or equal to that of the most sonorous segment λ for which

$${}^{*}\text{P}/\lambda \gg -\text{C}\textsc{od},$$

as well as being less than the maximum sonority value π_{Ons} of possible onsets. This is just what the last line of (257) says.

Now (257) establishes:

(258) **Onset/Coda Licensing Asymmetry.** There are languages in which some possible onsets are not possible codas, but no languages in which some possible codas are not possible onsets.

The second half of this asymmetry was already established in (254). The first half follows from (257), which asserts that the most sonorous possible onsets λ will not be possible codas in any language which is not weakly coda averse and in which

$$-\text{COD} \gg {}^{*}\text{P}/\lambda.$$

Since there are no universal principles violated in such languages, they are indeed possible according to the Basic Segmental Syllable Theory (214). The following tableau illustrates a language in which *d* but not *i* is a possible coda, while both are possible onsets.

(259) **Example Tableau for a Language in which Codas License Fewer Segments than Onsets:**

	PARSE	*M/□	*P/*d*	*P/□	−COD	ONS	*M/*i*	*P/*i*	*M/*d*
/tad/ →									
☞ .tád.					*				*
.tá.d□́.				* !					*
.tá.d́.			* !			*			
.tá.□d́.		* !	*						
.tá.⟨d⟩	* !								
/tai/ →									
.tái.					* !		*		
.tá.i□́.				* !			*		
☞ .tá.í.						*		*	
.tá.□í.		* !						*	
.tá.⟨i⟩	* !								
/ia/ →									
☞ .iá.							*		
.í.á.						* ! *		*	
.□í.□á.		* ! *						*	
.⟨i⟩á.	* !					*			

In this tableau, we have omitted the marks incurred by *t* and *a*. By (256), for the two inputs of the form /taλ/, we need only consider candidate parses beginning *.tá*···., and in all these candidates the marks for *tá* cancel. For /ia/, it follows that the optimal parse is *.iá*. by the proof (at the very end of §8.2.6) of (237), in which /τa/ was shown to be parsed as *.τá.* whenever τ satisfies the Possible Onset Conditions; these are satisfied for τ = *i* because (231. [ii]) holds by inspection of (259):

{ONS, *M/□} ≫ *M/*i* ≫ *P/*i*.

is satisfied for τ = *i*. In (259) we show some competitors simply for illustration. Since all these competitors also parse *a* as a peak, we can omit the cancelling marks *M/*a*.

This tableau (259) illustrates that *d* is a possible coda (/tad/ → *.tád.*), and while *i* is a possible onset (in /ia/ → *.iá.*), it is not a possible coda (/tai/ → *.tá.í.*).

This same example of a language in which codas license fewer segments than onsets is analyzed more completely in the following diagram (260), which shows the crucial ranking dependencies. Here the example illustrated in (249) has been extended to show the possible codas, delimited by π_{Cod}. The possible nuclei shown in (249) have been omitted here, but the possible onsets have been retained for comparison with the possible codas.

(260) **Deriving the Possible Coda Parameter π_{Cod}: An Example**

Decreasing Constraint Dominance →

a.	*t* ← Poss. Codas → *d*
b.	π_{Cod}
c.	=|*d*|
d.	**PARSE** ***P/□** | **−COD**
e.	***P/*t*** ***P/*d*** ***P/*f*** ··· ***P/*l*** ***P/*i*** ***P/*a***
f.	≫
g.	***M/*a*** ***M/*i*** ***M/*l*** ··· ***M/*d*** ***M/*t***
h.	**PARSE *M/□** **ONS**
i.	=$\mathbf{C_{Ons}}$ |*i*|=
j.	π_{Ons}
k.	*i* ← Possible Onsets → *t*

Lines e−k of (260) are identical to lines e−k of (249). In line d, we have shown that −COD is lower ranked than PARSE and *P/□, as required by (250) in order than any codas be possible. The ranking of −COD relative to the associational constraints *P/□ and *M/□ now determines π_{Cod} (257). We must first find the most sonorous segment λ for which $*P/\lambda \gg -\textsc{Cod}$; this is *d*. We must then set π_{Cod} equal to the lower of the sonority values $|d|$ and $\pi_{Ons} = |i|$; so $\pi_{Cod} = |d|$, as noted in lines b–c. This means that all segments at most as sonorous as $|d|$ are possible codas (257), as noted in line a. Here we see an example where codas are more restricted than onsets, comparing lines a and k. As in (249), however, the figure is potentially a bit confusing because the direction of the sonority scales in lines a and k is reversed. This arises for the same reason here as it did in (249); like nuclei, the possible codas are determined (in part) by the locations of the constraints $*P/\lambda$, while the possible onsets are determined only by the locations of the constraints $*M/\lambda$. The figure does not explicitly show that a possible coda is necessarily a possible onset.

In this example, the segments with sonority levels higher than $\pi_{Cod} = |d|$ but not higher than $\pi_{Ons} = |i|$ are possible onsets but not possible codas. These same segments are also possible nuclei (249). Indeed this is always the case:

(261) **PossOns−PossCod ⊂ PossNuc.** In a language with some possible codas, if λ is a possible onset but not a possible coda, then λ must also be a possible nucleus.

Proof. The language must not be weakly coda averse, for if it were, all possible onsets would be possible codas (257), and no such λ would exist. Given that the language is not weakly coda averse, and that λ is a possible onset, λ must fail to be a possible coda in virtue of failing to satisfy condition (251.[vi]); i.e., we must have:

$-\textsc{Cod} \gg *P/\lambda$.

Since codas are possible in the language, by (250) we must in addition have

$\{\textsc{Parse}, *P/\square\} \gg -\textsc{Cod} \gg *P/\lambda$.

This implies that λ satisfies the Possible Peak Condition (230.[3]):

$*P/\square$ or $*M/\lambda \gg *P/\lambda$

and that λ is a tenable peak (225):

$\textsc{Parse} \gg *P/\lambda$;

these two properties mean that λ satisfies the Possible Peak Sufficient Condition (235).

There are two aspects of our onset/coda licensing asymmetry which must be distinguished. On the one hand, from the fact that $-\textsc{Cod}$ asserts that Cod is a marked structural position, we derive the fact that universally, inventories of codas are more restricted than those of onsets. The structural markedness of Cod entails that it is a weak licenser.

On the other hand, there is the particular nature of the relative restrictiveness of codas vis à vis sonority: that of the onset inventory the portion admitted into the coda inventory are the *least* sonorous segments. This is empirically unsatisfactory in that the most Harmonic codas are generally regarded to be those which are *most* sonorous (Prince 1983, Zec 1988, in prep., Clements 1990). This inadequacy can be traced to the fact that we have treated codas and onsets identically as ‘margins’, in contrast with peaks. This is a reasonable first step beyond the CV theory, of course, since codas and margins are both ‘C’ positions in contrast to the ‘V’ position of peaks. On the other hand, refinements of this first step are clearly desirable. We have captured the commonality of coda and onset, but have ignored the fact that compared to the onset, the coda position is more structurally close to the peak: perhaps in the sense that both comprise the rime, or in that both are moraic.

So a refinement of the account presented above which immediately suggests itself is the following. If a segment λ is parsed in onset position, it incurs the associational mark *M/λ; if in peak position, *P/λ; if in coda position, *both* *M/λ and *P/λ: the former because the coda is a margin position, the second because it is moraic (or in the rime). This refinement captures the relationship of coda to both onset and to nucleus.

The way these relationships are captured, however, makes the coda position symmetrically related to both onset and nucleus, going too far in the direction of respecting the coda/nucleus relationship. For if the kind of analysis we have presented in this section is repeated with this new approach, the conclusion turns out to be that a possible coda must be an ambidextrous segment. This result is not surprising given that the marks a segment incurs when parsed as a coda include as a proper subset the marks it would incur as either an onset or a nucleus. And this result succeeds in shifting the coda inventory from the least to the most sonorous portion of the onset inventory — but overenthusiastically, including only those onsets which are so sonorous as to be themselves possible nuclei.

And assigning two marks {*M/λ, *P/λ} to Cod/λ while only one mark to either Ons/λ and Nuc/λ makes the coda position inherently more marked that the other positions, above and beyond the structural mark *−COD which is the sole source of the greater markedness of Cod in the approach developed above. There are several related alternatives which assign two marks to *all* syllable positions; the simplest of which assigns {*M/λ, *P/λ} to Cod/λ, {*P/λ, *P/λ} to Nuc/λ, and {*M/λ, *M/λ} to Ons/λ. A somewhat more complex approach introduces a separate Rime Hierarchy of constraints *R/λ which is aligned with sonority like the Peak Hierarchy (more sonorous segments making more harmonic rimes); in such an account, Cod/λ incurs {*M/λ, *R/λ}; Nuc/λ incurs {*P/λ, *R/λ}, and Ons/λ {*M/λ, *M/λ}. This last approach breaks the symmetry of the relations between Cod and Nuc on the one hand and Cod and Ons on the other, a symmetry afflicting the previous alternatives. And this has the consequence that possible codas are necessarily possible onsets but not necessarily possible nuclei.

The merits of these more complex approaches relative to each other and to the simplest account developed in this section are largely yet to be explored. One conclusion, however, should be clear. The basic result at the core of the onset/coda licensing asymmetry which comes out of Optimality Theory is that the structural markedness of Cod entails that it is a weak licenser. The particular *nature* of the restrictions applying to codas, however, depends on details of the treatment of codas which are yet to be seriously explored; in this section, we have examined only the very simplest of possibilities.

8.3.3 An Example: Berber, Take 2

We now illustrate the Basic Segmental Theory (214) by applying our results to the analysis of Berber. We repeat for convenience our previously determined constraint hierarchy (200):

(262) **Berber Hierarchy:** {ONS, PARSE, *P/□, *M/*a*} ≫ *M/□ ≫ HNUC ≫ −COD

First, from (262) we see that Berber is weakly coda averse (253):

{ONS, *M/□} ≫ −COD.

Thus the possible codas are the same as the possible onsets; we can refer to them simply as the possible margins. The hypothetical example illustrated in (249) can be modified to accommodate the domination hierarchy (200) of Berber. We also modify it to reflect the fact that in Berber, all segments are possible peaks and all segments except *a* are possible margins:

(263) **Determining Parameters for Berber**

Decreasing Constraint Dominance →

a.			*t* ←	Possible Nuclei	→ *a*
b.			π_{Nuc}		
c.	**C_{Nuc}**=		=|*t*|		
d.	**{PARSE, *P/□}**				
e.			***P/*t***	···	***P/*a***
f.				??	
g.		***M/*a***	***M/*i***	···	***M/*t***
h.	**{PARSE, ONS}**		***M/□**		
i.			=**C_{Ons}**	|*i*|=	
j.				π_{Ons}	
k.				*i* ← Possible Margins	→ *t*

The relative ranking of the associational constraints {*P/*t*, ···, *P/*a*} and {*M/*i*, ···, *M/*t*} need to be determined by considering the Dell-Elmedlaoui algorithm, which resolves in a certain way the inherent conflict between trying to maximize nuclear vs. marginal Harmony, or, to minimize nuclear vs. marginal markedness. Consider the following hypothetical inputs:

(264) **Berber Peak and Margin Hierarchies.**

	*M/*f*	*M/*d*	*M/*t*	*P/*t*	*P/*d*	*P/*f*
/tkt/ →						
☞ .t́.kt́.			[*]	{*} *		
.tkt́.			[*] * !	{*}		
/fdt/ →						
☞ .f́.dt́.		*		*		*
.fd́t.	*		*		*	

The Dell-Elmedlaoui algorithm gives *.t́.kt́.* as the correct parse of /tkt/. It is instructive to compare this correct parse to the competitor *.tḱt.*, shown in the tableau (264). This tableau shows the relevant portions of the Peak (204) and Margin (207) Hierarchies; at this point we do not know how these rank relative to one another. Comparing these two alternative parses, we have cancelled a matching pair of *M/*t* marks, enclosed in square brackets, and a pair of *P/*t* marks enclosed in curly brackets. The two remaining marks are *P/*t* for the correct parse and *M/*t* for the incorrect parse (remembering that since $|k| = |t|$, *k* is treated like *t* by the constraints of both hierarchies). That is, since all sonority values are equal, the correct parse has one more peak (incurring *P/*t*) and the incorrect parse one more margin (earning *M/*t*). In order that the correct parse (the one with more peaks) be the more harmonic, we must have *M/*t* ≫ *P/*t*. Since *M/*t* is the bottom of the Margin Hierarchy and *P/*t* the top of the Peak Hierarchy, this entails that the entire Margin Hierarchy must be ranked higher than the entire Peak Hierarchy.

The second example illustrated in (264) is perhaps clearer. The least harmonic peak in the correct parse of /fdt/, *t́*, is less harmonic than the least harmonic peak in the incorrect parse, *d́*. Thus if the Peak Hierarchy were dominant, the incorrect parse would be chosen, in order to avoid the least harmonic peak. The correct result does however arise by placing the Margin Hierarchy above the Peak Hierarchy: for the least harmonic margin in the incorrect parse, *f*, is less harmonic than the least harmonic margin in the correct parse, *d*.

As pointed out in fn. 10 of §2, p. 17, and briefly mentioned in §8.1.2, there are two equivalent harmonic ways of viewing the Dell-Elmedlaoui algorithm. The simplest is as a procedure which scans unsyllabified material in a string for the most harmonic nucleus, and makes it the nucleus of a new syllable. The other is as a procedure which scans for the least harmonic potential margin, and it makes the nucleus of a new syllable.

The operations performed under either description are identical. While the first formulation has the virtue of simplicity, it has a decided disadvantage as far as the current enterprise is concerned: it evaluates (nuclei) from most to least harmonic. As long as this is confined within a single constraint HNUC, this falls within the purvue of Optimality Theory (as formally explained in §5.2.1.2). But in §8 the work done within the single constraint HNUC is now distributed over multiple constraints in the Peak and Margin Hierarchies. These marks assessed by these constraints are scattered across the columns of constraint tableaux, and these marks operate in harmonic evaluation from worst to best, i.e., from those incurred by the least harmonic structures first. The 'worst first' aspect of harmonic evaluation concords with the second formulation of the Dell-Elmedlaoui algorithm, which scans for the least harmonic potential margin and parses it as a nucleus. This is a consequence of the fact derived through (264), that the Margin Hierarchy dominates the Peak Hierarchy in Berber. In the example of /fdt/ (264), the most sonorous segment *f* controls the parsing by means of the highest-ranked (relevant) margin constraint *M/*f*, which must be satisfied if at all possible, and not by the lowest-ranked (relevant) peak constraint *P/*f*.

Another way of seeing why the Dell-Elmedlaoui algorithm in effect places the Margin Hierarchy higher than the Peak Hierarchy can be understood through the notion of affinity introduced earlier. Since the entire Margin Hierarchy outranks the entire Peak Hierarchy, we have for *every* segment λ that:

$$*M/\lambda \gg *P/\lambda,$$

i.e., that

$$*P/\lambda \succ *M/\lambda.$$

That is, *every segment is peak preferring*: most harmonic when parsed as a nucleus. For the Dell-Elmedlaoui descends the *entire* sonority hierarchy, preferring to construct (the most harmonic possible) peaks, being undetered even by voiceless stops. As long as this does not prevent (via other constraints such as ONS) a more sonorous segment from being parsed as a nucleus, even *t*s will be parsed as peaks rather than margins.[68]

So what aspects of the Dell-Elmedlaoui algorithm are explained by the Optimality Theoretic treatment of Berber? We have seen how the algorithm is a result of the operation of the Peak and Margin Hierarchies, when the Margin Hierarchy is dominant. Our analysis would also permit a language (Berber′) in which the Peak Hierarchy dominated the Margin Hierarchy. In Berber′, the winners and losers in (264) are exchanged: the parsing is driven to avoid the least harmonic peaks, thereby getting the most harmonic margins, rather than the other way around, as in Berber. The variant of the Dell-Elmedlaoui algorithm which implements syllabification in Berber′ scans the sonority hierarchy from least to most sonorous, at each stage constructing a new syllable in which the least-sonorous possible segment is parsed as a margin.

At the level of individual syllables Berber and Berber′ involve the same notion of syllabic well-formedness: minimum-sonority margins, maximum-sonority peaks. They differ only in multisyllabic comparisons, minimal cases of which are illustrated in (264). In multisyllabic parses, conflicts can arise between optimizing the nuclear Harmony of one syllable and optimizing the marginal Harmony of an adjacent syllable; Berber and Berber′ differ in whether the former or the latter has priority. And since harmonic ordering works by filtering out constraint violators starting with the worst, Berber's priority on optimizing nuclear Harmony is achieved by filtering out first those parses in which the most harmonic potential nuclei have been parsed as margins, that is, those with the least harmonic margins. In Berber, the Margin Hierarchy dominates, giving rise to multisyllabic parses in which optimizing nuclear Harmony has higher priority than optimizing marginal Harmony. The reverse is true in Berber′. But both Berber and Berber′ share the universal Harmony scales determining what constitutes a more harmonic nucleus or a more harmonic margin.

What is important to note is that our theory completely rules out syllabication systems which construct syllables with minimum-sonority nuclei or maximum-sonority margins. Such systems would arise from a variant of the Dell-Elmedlaoui algorithm in which the sonority scale was descended from top to bottom, and at each stage the most sonorous available segment was parsed as a margin. Or a variant in which the sonority scale was mounted from bottom to top, the least sonorous available segment being parsed as a nucleus. Such syllabification systems ruled out by our theory correspond to harmonic syllable systems in which the Peak Hierarchy is inverted ($*P/a \gg \cdots \gg *P/t$) and likewise for the Margin Hierarchy. In other words, our theory universally restricts the ranking of constraints within the Peak sub-Hierarchy which determine the relative Harmony of different nuclei, and similarly for margins. What it leaves open for cross-linguistic variation is the

[68] In fact, as pointed out in §2.1, we are abstracting away from certain complications which are not handled by the Dell-Elmedloui algorithm, including effects which Dell and Elmedlaoui treat with subsequent desyllabification rules operating at word boundaries. It may well be possible to incorporate such additional complexities into the present account via constraints which are sensitive to boundaries, and perhaps by reconsidering whether the Margin Hierarchy *completely* dominates the Peak Hierarchy (that is, whether even the obstruents are all peak preferring).

way the Peak and Margin Hierarchies rank relative to each other. If the entire Margin Hierarchy dominates the entire Peak Hierarchy, all segments are peak-preferring and we get Berber; the other way around, and we get Berber′. As the analysis in §8 has shown, if the two hierarchies intersect, we get more typical syllabic systems in which some number of the most sonorous segments can be peaks, and some number of the least sonorous can be margins.

We can now return to the overall analysis of Berber which helped motivate the Segmental Theory in the first place. The Berber constraint hierarchy (262) can now be given as:

(265) **Berber**

{ONS, PARSE, *P/□, *M/*a*} ≫ *M/□ ≫ [*M/*i* ≫ ··· ≫ *M/*t*] ≫ {−COD, [*P/*t* ≫··· ≫ *P/*a*]}

The constraint ‘HNUC’ of (200) has been replaced by the lower portion of the Margin Hierarchy [*M/*i* ≫ ··· ≫ *M/*t*], and the Peak Hierarchy [*P/*t* ≫ ··· ≫ *P/*a*] has been ranked beneath the Margin Hierarchy. The relative ranking of −COD and the Peak Hierarchy appears to have no empirical consequences, so we leave this ranking unspecified.

As a simple illustration of (265), the following tableau shows one hypothetical example:

(266) **Berber**

/iun/ →	ONS, PARSE, *P/□	*M/*a* }	*M/□	*M/*i*	*M/*n*	*M/*t*	−COD	*P/*t*	*P/*n*	*P/*i*	*P/*a*
☞ .í.uń.				*					*	*	
.iún.				*	* !		*			*	
.í.□ún.			* !		*		*			* *	
.iú.n□́.	* !			*	*					*	

In this tableau, we have abbreviated the sonority hierarchy to *a* > *i* > *n* > *t* and considered a hypothetical input which involves only these three segments. We have arbitrarily positioned −COD left of the Peak Hierarchy, suggesting this arbitrariness by using a dotted line to separate them. The dashed lines are only used to help bind together the adjacent portions of the Margin and Peak Hierarchies, in anticipation of the next development.

8.4 Simplifying the Theory by Encapsulating Constraint Packages

8.4.1 Encapsulating the Association Hierarchies

The typology of segment classes we have developed, illustrated in the diagrams (249) and (260), suggests that we may reduce the number of constraints, and enhance the interpretability of the analysis, by encapsulating portions of the Peak and Margin Hierarchies into the following derived (parameterized) constraints:

(267) **POSS-NUC(π_{Nuc}):** *Interpretation:* Segments with sonority less than π_{Nuc} may not be parsed as peaks.
Abbreviates: [*P/*t* ≫ ··· ≫ *P/τ], where τ is the most sonorous segment with $|\tau| < \pi_{Nuc}$.
Ranking: Above C_{Nuc}. Hence, unviolated.

(268) **POSS-MAR(π_{Ons}):** *Interpretation:* Segments with sonority greater than π_{Ons} may not be parsed as margins.
Abbreviates: [*M/*a* ≫ ··· ≫ *M/α] where α is the least sonorous segment with $|\alpha| > \pi_{Ons}$.
Ranking: Above C_{Ons}. Hence, unviolated.

(269) **POSS-COD(π_{Cod}):** *Interpretation:* Segments with sonority greater than π_{Cod} may not be parsed as codas.[69]
Ranking: Sufficiently high to be unviolated.

(270) ***P:** *Interpretation:* The lower $|\lambda|$, the more marked the association P/λ.
Abbreviates: [*P/ζ ≫ ··· ≫ *P/*a*], where $|\zeta| = \pi_{Nuc}$.
Ranking: Below C_{Nuc}.

(271) ***M:** *Interpretation:* The higher $|\lambda|$, the more marked the association M/λ.
Abbreviates: [*M/ρ ≫ ··· ≫ *M/*t*], where $|\rho| = \pi_{Ons}$.
Ranking: Below C_{Ons}.

Together with the Basic Syllable Structure Constraints (114−120), these constraints define the **Encapsulated Segmental Syllable Theory**. We discuss them in turn.

The constraints POSS-NUC and POSS-MAR are unviolated by construction. POSS-NUC and POSS-MAR each encapsulate by definition exactly those associational constraints *P/λ or *M/λ which we have

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[69] The discussion at the end of §8.3.2 introduces several possible refinements of the account of codas developed here. All these refinements have as a consequence that the coda inventory is governed by *two* parameters ranging over the sonority scale: a lower limit as well as an upper limit.

through rather extensive analysis shown to be unviolated in all outputs. They also each encapsulate just those associational constraints which dominate what we have shown to be a critical constraint (246): either C_{Nuc} (the lowest-ranked of PARSE, ONS, and *M/□) or C_{Ons} (the lowest-ranked of PARSE and *P/□). Thus the positions of POSS-NUC and POSS-MAR in the constraint hierarchy must reflect this, and the restrictions on the allowed rankings of these constraints are noted in (267) and (268). That the derived constraint POSS-X (X = NUC or MAR) dominate the corresponding Basic Syllable Structure Constraint C_X is sufficient (as our analysis has shown) to ensure that they are unviolated, and so it does not matter *where* each is ranked above C_X.

It is clear that POSS-NUC and POSS-MAR constitute a reconstruction within the Basic Segmental Syllable Theory (214) of the analogs of the two universally high-ranked constraints of the Basic CV Syllable Theory (123):

*P/C: C may not be parsed as a peak (122), and
*M/V: V may not be parsed as a margin (121).

The constraint POSS-COD is less directly constructed. In languages without onset/coda licensing asymmetries, where $\pi_{Cod} = \pi_{Ons}$, such a constraint is not needed; POSS-MAR suffices to block illegal associations to both Ons and Cod. So consider a language in which there is a segment λ which is a possible onset but not a possible coda ($\pi_{Cod} < \pi_{Ons}$). Associations Cod/λ must be blocked, but not by blocking M/λ, since Ons/λ is legal. The arrangement of Basic Segmental Syllable Theory constraints that conspires to block Cod/λ is more spread out than that which blocks Ons/α for an illegal onset α (simply, *M/λ $\gg C_{Ons}$). Included is the requirement (257) that −COD ≫ *P/λ, but neither −COD nor *P/λ can be absorbed into a derived constraint POSS-COD. We therefore simply define POSS-COD by its interpretation in (269), without reducing its definition to an abbreviation of associational constraints. We also simply assert that it must be sufficiently highly ranked to be unviolated, without stating precisely what constitutes a high enough ranking to ensure this.

The constraints *P and *M encapsulate the lower portions of the Peak and Margin Hierarchies, respectively: the portions remaining after the highest parts have been incorporated into the POSS-NUC and POSS-MAR constraints. As discussed in §8.3.3 in the context of Berber, the constraints *P constitutes a reconstruction of HNUC, but with a subtle change: *P evaluates marks from worst to best, whereas HNUC evaluates marks from best to worst. (This difference among constraints was discussed formally at the end of §5.2.1.2 in terms of the order in which constraints list the marks incurred by entire parses.) Like HNUC, the constraints *P and *M are non-binary, and their use in ranking competing structures is a bit more complex than with the binary constraints they encapsulate. Remembering that they are mere abbreviations for portions of the Peak and Margin Hierarchies, respectively, it is clear that to use them in a constraint tableau, under *P one lists all the marks *P/λ incurred by a candidate, starting from the worst. Then to compare two candidates' violations of *P, we tick off their respective marks *P/λ starting from the worst. When the two candidates share a particular mark *P/λ, that mark cancels. As soon as one candidate reaches a mark that is not cancelled by the other, the candidate with the worst mark loses. We illustrate with our canonical example.

8.4.2 An Example: Berber, Take 3

Using the encapusalated constraints, we can rewrite the Berber constraint domination heirarchy (265) as follows:

(272) **Berber:** {ONS, PARSE, *P/□, POSS-MAR} ≫ *M/□ ≫ *M ≫ {−COD, *P}

POSS-COD is unnecessary, merely repeating POSS-MAR, since there is no onset/coda licensing asymmetry. POSS-MAR is simply *M/*a*, since in Berber only *a* is not a possible margin. Note that POSS-MAR is indeed ranked higher than C_{Ons} ≡ min{PARSE, ONS, *M/□} = *M/□ in Berber, as required by (268). *M encapsulates all the Margin Hierarchy except *M/*a* = POSS-MAR, and, as required by (271), *M ranks lower than C_{Ons}. Since all segments are possible nuclei in Berber, POSS-NUC vanishes, and *P is the entire Peak Hierarchy. As required by (270), *P ranks lower than C_{Nuc} ≡ min{PARSE, *P/□} in Berber.

We illustrate this encapsulated account of the Berber analysis (272) by showing the resulting tableau which encapsulates (266):

(273) **Berber:**

/iun/ →	{ONS, PARSE, *P/□	POSS-MAR}	*M/□	*M			−COD	*P			
		*M/*a*		*M/*i*	*M/*n*	*M/*t*		*P/*t*	*P/*n*	*P/*i*	*P/*a*
☞.í.uń.				**i*					**n*	**i*	
.iún.				**i*	**n* !		*			**i*	
.í.□ún.			* !		**n*		*			**i* **i*	
.iú.ń□.	* !			**i*	**n*					**i*	

8.4.3 Sufficiency and Richness of the Encapsulated Theory

In the preceding analysis of Berber, the Encapsulated Segmental Syllable Theory was sufficient to re-express the earlier Basic Segmental Syllable Theory analysis. This is because it was not necessary to insert additional constraints into the midst of the portions of the Peak and Margin Hierarchies that are encapsulated by *P and *M. How generally this will turn out to be the case is an open question. There seems to be no obvious principle that would prevent such intrusions of additional constraints.

It is also somewhat unclear whether the Encapsulated Theory has sufficient expressive power to cover all analyses possible within the Basic Segmental Syllable Theory. For example, if *P and *M are ranked as wholes one above the other, as required by the Encapsulated Theory, this does not permit expression of the general patterns of interdigitating the Peak and Margin Hierarchies which are possible with the Basic Theory. We are no longer free, for example, to independently manipulate the parameter π_{Aff} which determines the sonority value separating peak- from margin-preferring segments.

It is however not clear whether this limitation reduces the languages which can be analyzed. We do know that some languages analyzable within the Basic Theory require −COD to be inserted within the constraints encapsulated by *P. Consider a language which allows:

{*t*, ···, *i*} as onsets,
only {*t*, *d*} as codas, and
{*d*, ···, *a*} as peaks.

This possibility would be illustrated by (249) and (260), if in (249) *P/*d* were down-ranked slightly, below C_{Nuc} = *P/□. Encapsulating this analysis,

POSS-NUC ≡ *P/*t*,

since *t* is the only impossible nucleus. Thus

*P ≡ [*P/*d* ≫ *P/*f* ≫ ··· ≫ *P/*a*].

But in order that *d* but not *f* be a possible coda, while both are possible onsets, we must have, by the Possible Coda Parameter expression (257):

*P/*d* ≫ −COD ≫ *P/*f*.

So −COD must insert itself into the constraints encapsulated by *P in order to separate the legal from illegal codas.

However, this language *does* seem to be analyzable in the Encapsulated Theory, even though −COD cannot be inserted into *P now treated as a single constraint. This is achieved simply by setting $\pi_{\text{Cod}} = |d|$ in POSS-COD.

Yet even if the Encapsulated Theory does turn out to offer less generality of analysis than the Basic Theory with its full hierarchies of associational constraints, it appears to be worthwhile determining whether analysis within the Encapsulated Theory is possible before resorting to the more complex Basic Theory. The general conception of constraint encapsulation can be applied in other ways than in (267)−(271), and other modes of encapsulation may be appropriate under certain ranking conditions.

Were it not for the influence of our primary example, Berber, where HNUC has been the driving force for our analysis, one might have been tempted to try a more Boolean encapsulation strategy. The segmental inventory having been divided into the classes (242), we might try to simply define constraints that rule out all impossible associations, and leave it at that. Aside from the role of sonority in separating the classes of possible nuclei, possible onsets, and possible codas from one another, sonority would then play no role *within* the classes themselves. This would amount to adopting the parametrized high-ranking (unviolated) constraints POSS-NUC, POSS-MAR, and POSS-COD, but omitting the constraints *P and *M which serve to distinguish the relative Harmonies of possible associations. In such a theory, all the segments within a given class would be distributionally equivalent.

It is worth emphasizing that this alternative Boolean encapsulation would fail rather seriously to do justice to the Basic Segmental Syllable Theory. We have of course seen many examples of the role of sonority in governing syllabification within the large class of ambidextrous segments in

Berber. Indeed, the following example shows that, at least in languages that permit codas, Berber-like syllabification is universal within the class of ambidextrous segments:

(274) **Sonority is Operative within the Class of Ambidextrous Segments**

$/\text{tat}\lambda_1\lambda_2/ \rightarrow$

$.\text{tá.t}\,\acute{\lambda}_1\lambda_2.$	$*\text{P}/\lambda_1$, $*\text{M}/\lambda_2$
$.\text{tát.}\lambda_1\acute{\lambda}_2.$	$*\text{M}/\lambda_1$, $*\text{P}/\lambda_2$

Here λ_1 and λ_2 are two ambidextrous segments: possible nuclei, margins, and codas. By (256) we know that the initial /ta/ is parsed *.tá*. The question is whether the segments $\lambda_1\lambda_2$ will be parsed as the rime of a closed syllable starting with *t*, or as an open syllable, leaving the second *t* to close the first syllable. The marks incurred by λ_1 and λ_2 are shown in (274). Clearly, if $|\lambda_1| > |\lambda_2|$, then both the marks $*\text{P}/\lambda_1$ and $*\text{M}/\lambda_2$ of the first parse are dominated by the marks of the second, thanks to the Peak (204) and Margin (207) Hierarchy. For in this case λ_1 is a more harmonic peak *and* λ_2 is a more harmonic margin. If, on the other hand, $|\lambda_1| < |\lambda_2|$, then the reverse holds and the second parse is the optimal one. Thus within the ambidextrous segments, sonority operates within syllabification to find the optimal nuclei, as in Berber.

To see how sonority differences affect syllabification even within the classes of pure onsets and pure peaks, consider a deletion language, one where $\{\text{O}\textsc{ns}, *\text{M}/\square = \text{F}\textsc{ill}^{\text{Ons}}, *\text{P}/\square = \text{F}\textsc{ill}_{\text{Nuc}}\} \gg$ PARSE. First suppose τ_1 and τ_2 are pure onsets: they are possible onsets but not possible peaks. Consider the following example:

(275) **Sonority is Operative within the Class of Pure Onsets**

$/\tau_1\tau_2 a/ \rightarrow$

$.\langle\tau_1\rangle\tau_2\text{á}.$	$*\text{M}/\tau_2$
$.\tau_1\langle\tau_2\rangle\text{á}.$	$*\text{M}/\tau_1$

Since we are in a deletion language, the prefered repair here will be deletion. The question is, which consonant will be deleted? If τ_1 is deleted, the onset incurs the mark $*\text{M}/\tau_2$; and likewise with 1 and 2 interchanged. The least marked onset will contain the least sonorous segment, so the more sonorous segment is the one to delete. Thus sonority differences within the class of pure consonants are operative in syllabification.

The parallel example for pure peaks α_1 and α_2 is:

(276) **Sonority is Operative within the Class of Pure Peaks:**

$/\text{t}\alpha_1\alpha_2/ \rightarrow$

$.\text{t}\langle\alpha_1\rangle\acute{\alpha}_2.$	$*\text{P}/\alpha_2$
$.\text{t}\acute{\alpha}_1\langle\alpha_2\rangle.$	$*\text{P}/\alpha_1$

Here, it is the *least* sonorous segment that deletes, to create the most harmonic nucleus.