

**Derivational Phonology and Optimality Phonology:  
Formal Comparison and Synthesis**

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## ABSTRACT

This thesis conducts a formal comparison of Optimality Theoretic phonology with its predecessor, Rule-based Derivational phonology. This is done in three studies comparing (i) rule operations and Faithfulness constraint violations, (ii) serial rule interaction and hierarchical constraint interaction, and (iii) derivational sequences and harmony scales. In each, the extent of the correlation is demonstrated, and empirical implications of their differences drawn out. Together, the studies demonstrate that there is no case in which the two frameworks mimic each other at all three points at once: the “Duke of York gambit”, where one rule is reversed by another, is the one case where rule ordering and constraint ranking converge, yet the complexity of this composite mapping demonstrably exceeds that of the input-output mappings of Optimality Theory. It is also argued that the Duke of York mapping is generally unexplanatory, and that its availability falsely predicts that a vowel inventory may be reduced to one in some contexts by deletion and then insertion. The failure of this prediction is illustrated from Yokuts, Chukchee and Lardil.

A synthesis of derivational and optimality phonology is then presented in which constraints accumulate one by one (Constraint Cumulation Theory, CCT). This successfully describes patterns of overapplication, mutual interdependence, and default, each of which was previously captured in one of the systems but not replicated in the other. It also automatically excludes Duke of York derivations except for some attested subtypes. The way the model handles overapplication and underapplication leads to the further prediction that neutralisation and elision processes are transparent except when neutralisation occurs as part of a stability effect – a result which draws on the resources of contemporary phonology to resolve the ‘unmarked rule ordering’ problem from the 1970s, and reinforces the traditional distinctions of neutralisation vs. conditioned variation, and elision vs. epenthesis.

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## CONTENTS

<b>1: FORMAL THEORY COMPARISON.....</b>	<b>1</b>
<b>1.1 What is Formal Theory Comparison?.....</b>	<b>3</b>
<i>1.1.1 Automata and Rewriting Systems.....</i>	<i>3</i>
<i>1.1.2 Autosegments and Prosodies.....</i>	<i>7</i>
<i>1.1.3 Further Remarks.....</i>	<i>11</i>
<b>1.2 Formal Comparison and Data-centred Comparison.....</b>	<b>13</b>
<i>1.2.1 Derivation and Optimisation as Descriptions of a Function .....</i>	<i>13</i>
<i>1.2.2 Describing Functions.....</i>	<i>17</i>
<i>1.2.3 From Data to Grammars.....</i>	<i>19</i>
<b>1.3 Formal Comparison and Substantive Comparisons.....</b>	<b>21</b>
<i>1.3.1 Substantive Universals in Derivational and Optimality Theory.....</i>	<i>21</i>
<i>1.3.2 Formal Universals in Derivational and Optimality Theory.....</i>	<i>22</i>
<b>1.4 Form and Semantics.....</b>	<b>25</b>
<i>1.4.1 Bromberger and Halle (1997).....</i>	<i>26</i>
<i>1.4.2 Assumptions: A Critique.....</i>	<i>29</i>
<i>1.4.3 From Semantics To Syntax.....</i>	<i>34</i>
<b>1.5 Conclusion.....</b>	<b>36</b>
<b>2: SPECIFYING THE FRAMEWORKS: GENERATION VERSUS</b>	
<b>EVALUATION.....</b>	<b>37</b>
<b>2.1 Generation in the Derivational Framework.....</b>	<b>38</b>
<i>2.1.1 Derivational Sequences.....</i>	<i>38</i>
<i>2.1.2 What Is A Rule?.....</i>	<i>40</i>

2.1.3 <i>Rule Ordering and Regular Sequencing Constraints</i> .....	43
2.1.4 <i>Summary: Rule-Based Grammar</i> .....	46
<b>2.2 Evaluation in the Derivational Framework</b> .....	48
2.2.1 <i>Blocking Constraints</i> .....	48
2.2.2 <i>Constraints Triggering Repairs</i> .....	53
<b>2.3 Generation in the Optimality Framework</b> .....	55
2.3.1 <i>Is Optimality Theory Derivational?</i> .....	56
2.3.2 <i>How Are Candidates Admitted?</i> .....	57
2.3.3 <i>The Theoretical Role of Gen</i> .....	60
2.3.4 <i>Maintaining Accountability To The Input</i> .....	65
2.3.5 <i>Optimality Theory Without Gen</i> .....	69
<b>2.4 Evaluation in the Optimality Framework</b> .....	71
2.4.1 <i>Optimality</i> .....	71
2.4.2 <i>Optimality-Theoretic Constraints</i> .....	75
2.4.3 <i>The Structure of Optimality Theoretic Grammar</i> .....	82
<b>2.5 Programme For Structural Comparison</b> .....	83
<b>3: THE UNDERLYING FORM – SURFACE FORM CORRESPONDENCE</b> .....	84
<b>3.1 Operations and Faithfulness Violations</b> .....	85
<b>3.2 Input-Output Correspondence and Derivational History Relations</b> .....	86
3.2.1 <i>Input-Output Correspondences</i> .....	86
3.2.2 <i>Derivational History Relations</i> .....	88
3.2.3 <i>Identifying The Two</i> .....	92
3.2.4 <i>Hidden Operations</i> .....	93
3.2.5 <i>Representative Derivational History Relations</i> .....	97

3.2.6 <i>Summary</i> .....	100
<b>3.3 Natural Correspondences</b> .....	101
3.3.1 <i>Veritable Correspondence</i> .....	101
3.3.2 <i>Minimal Violation of Faithfulness Constraints</i> .....	103
3.3.3 <i>Insertion, Deletion, and Relocation</i> .....	110
3.3.4 <i>Economy of Derivation</i> .....	114
3.3.5 <i>Economy and Representativity</i> .....	117
3.3.6 <i>Summary: Minimality of Violation &amp; Economy of Derivation</i> .....	119
<b>3.4 The Duke of York Gambit</b> .....	121
3.4.1 <i>The Trouble With The Duke of York Gambit</i> .....	121
3.4.2 <i>The Duke of York Gambit as Unexplanatory</i> .....	124
3.4.3 <i>Eastern Massachusetts r</i> .....	126
3.4.4 <i>Evidence Against The Duke of York Gambit</i> .....	129
3.4.5 <i>Resyllabification and Trans-Domain Interactions</i> .....	133
3.4.6 <i>Summary: A Universal Property</i> .....	135
3.4.7 <i>An Unsuccessful Proposal: The Elsewhere Condition</i> .....	136
<b>3.5 Conclusion</b> .....	137
<b>4: RULE INTERACTION AND CONSTRAINT INTERACTION</b> .....	139
<b>4.1 The Rule-Constraint Analogy</b> .....	139
<b>4.2 An Analysis of Serial Rule Interaction</b> .....	144
<b>4.3 Rule Interaction Versus Constraint Interaction</b> .....	153
4.3.1 <i>Translation From Rules To Constraints</i> .....	153
4.3.2 <i>Mutual Interdependence</i> .....	160
<b>4.4 Conflicting Structural Outcomes</b> .....	164

4.4.1 <i>Reciprocal Outcomes</i> .....	164
4.4.2 <i>Sub-reciprocal Outcomes</i> .....	166
4.4.3 <i>The Extent of Structure Preservation Between Rules and Constraints</i> .....	171
<b>4.5 Conclusion</b> .....	173
<b>5: DERIVATIONAL SEQUENCES AND HARMONY SCALES</b> .....	174
<b>5.1 The Derivation-Harmony Analogy</b> .....	174
5.1.1 <i>Paths and Landscapes</i> .....	174
5.1.2 <i>Structures and Candidates</i> .....	176
5.1.3 <i>Formulating The Analogy</i> .....	179
<b>5.2 The Extent of the Correlation</b> .....	180
5.2.1 <i>Last Step as Increment</i> .....	181
5.2.2 <i>Postconditions and Restraints</i> .....	184
5.2.3 <i>Typical Derivational Sequences</i> .....	187
5.2.4 <i>A Duke-of-York Derivation: Irreducible Harmony Drop</i> .....	190
5.2.5 <i>Summary</i> .....	192
<b>5.3 Restricting Sequences</b> .....	193
5.3.1 <i>Excluding Duke-of-York Derivations</i> .....	193
5.3.2 <i>Sequences are not Ordered Sets</i> .....	196
5.3.3 <i>Derivational Economy</i> .....	199
<b>5.4 Conclusion</b> .....	205
<b>Appendix: Scales Are Not Connected Sets</b> .....	206
<b>6: CONSTRAINT CUMULATION THEORY</b> .....	210
<b>6.1 Towards Multifarious Interaction</b> .....	210

6.1.1 <i>The Constraint Cumulation System</i> .....	212
6.1.2 <i>Descriptive Coverage</i> .....	214
6.1.3 <i>Selective Admission of Duke of York Interactions</i> .....	223
<b>6.2 Predicting Overapplication and Underapplication</b> .....	<b>228</b>
6.2.1 <i>The Failure to Reproduce "Counterfeeding"</i> .....	228
6.2.2 <i>Prespecification: Modern Hebrew</i> .....	231
6.2.3 <i>More Underapplication: SOURCE constraints</i> .....	247
6.2.4 <i>A Hypothesis</i> .....	254
6.2.5 <i>Transparency of Neutralisation: Yokuts</i> .....	260
<b>6.3 Conclusion</b> .....	<b>269</b>
<b>7: CONCLUSION</b> .....	<b>272</b>
7.1 <b>The Duke of York Gambit</b> .....	273
7.2 <b>A New Synthesis</b> .....	275
<b>REFERENCES</b> .....	<b>277</b>

**1:**

## **FORMAL THEORY COMPARISON**

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Formal considerations receive a varying amount of attention in linguistic theory. Work in formalisation in this century was initiated by Bloomfield (1926), and generative grammar was initiated as an inquiry into the characteristics of mathematical systems that generate the sentences of a language. The advantages of formalisation were summed up by Chomsky (1957:5) this way:

By pushing a precise but inadequate formulation to an unacceptable conclusion, we can often expose the exact source of this inadequacy and, consequently, gain a deeper understanding of the linguistic data. More positively, a formalized theory may automatically provide solutions for many problems other than those for which it was explicitly designed. Obscure and intuition-bound notions can neither lead to absurd conclusions nor provide new and correct ones, and hence they fail to be useful in two important respects.

I hope to show that these values carry over to the comparison of alternative theories. Poorly-defined comparisons become entangled in a multiplicity of issues. With formalised theories, comparison may proceed by formulating correspondences between their structures. This may demonstrate greater similarity than is intuitively apparent from differences of presentation or different historical roots. Or, by pushing a correspondence to the point where it breaks down, we can expose the exact difference between the theories, revealing the kind of data that is most pertinent for testing them against each other, potentially revealing the inadequacy of one, the other or both. Integrating one theory with the other may extend it in the way that is needed, or may constrain it in the way that is needed. Furthermore, solving one problem this way may automatically provide solutions to other problems.

These advantages are witnessed in the present study. I will formally compare two formal theories of phonology, derivational theory and optimality theory, leading to an integration of these two theories (in chapter 6). This creates an extended theory that achieves a greater descriptive coverage of sound patterns than either original theory, but it is also automatically

constrained in interesting ways.

Previously in phonology, formalisation has touched phonemic theory (Batog 1967), segmental rewriting rules (Chomsky and Halle 1968, Johnson 1972), the theory of autosegmental representation (Goldsmith 1976, Coleman and Local 1991, Bird 1995), declarative phonology (Bird 1991, Scobbie, Coleman and Bird 1997), and optimality theory (Prince and Smolensky 1993, McCarthy and Prince 1995, Moreton 1999, Samek-Lodivici and Prince 1999, Prince 2002). Some formalisation has been concerned with adapting phonology to certain computational paradigms, such as finite-state computation (Kornai 1991, Kaplan and Kay 1994, Bird and Ellison 1994, Ellison 1994, Frank and Satta 1998), dynamic programming (Tesar 1995) and constraint logic programming (Bird 1995). Bird (1995:1) gives new impetus to the case for formalisation, arguing that only formalised theoretical proposals are capable of being tested on computer over large reserves of data, a development that could lead to more reliable and enduring theories.

Different approaches to phonological representation have variously recognised prosody relations (Ogden and Local 1994), association relations (Goldsmith 1976), overlap relations (Bird and Klein 1990, Bird 1995), path relations (Archangeli and Pulleyblank 1994), dominance relations (Clements 1985, Bird 1995), dependency relations (Anderson and Ewen 1987), government relations (Kaye, Lowenstamm and Vergnaud 1985). The field of autosegmental generative phonology now witnesses features, timing and weighting units, metrical stars and brackets, organised in tree and graph structures of two and three dimensions (Goldsmith 1990, Roca 1994, Kenstowicz 1994). While experimenting with notation may allow the best ideas to emerge (Goldsmith 1979:221), Bird and Ladd (1991) expose in detail the level of formal ambiguity and indeterminacy that the manipulation of these notations has reached.

The emergence of the constraint-based approaches of declarative phonology and optimality theory has signalled a revival of formalisation in phonology. However, we now have a

plurality of theoretical frameworks, each with its own approach to analysing sound patterns. Formal theory comparison offers the prospect of clarifying the issues raised by competing theories and reducing reliance on anecdotal views of the relation between them. This should sharpen debate, and further understanding of phonology amidst theoretical divergence.

In the remainder of the chapter we will motivate formal theory comparison of derivational phonology and optimality phonology in a number of ways. First, we will characterise what formal comparison is with a survey of some examples of theory comparison (1.1). Then, turning to derivational theory and optimality theory, we will contrast our proposed formal comparison with comparisons based on data, on substance, and on semantics (1.2-1.4). Each section will deliver a particular motivation for doing formal comparison.

## 1.1 What is Formal Theory Comparison?

While the comparison of different theoretical approaches is not new to linguistic texts, structural comparison of formal systems is less well developed than, say, comparisons of the generalisations over some data expressed by different proposals. Nevertheless, we now outline the successful comparison of rewriting grammars and automata in formal language theory. Then we review a less successful informal comparison between autosegmental phonology and prosodic analysis.

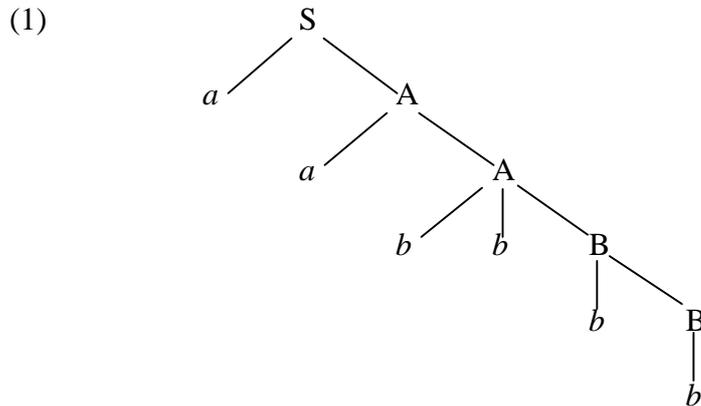
### *1.1.1 Automata and Rewriting Systems*

In formal language theory, good correlations hold between certain classes of **rewriting systems** and certain classes of **automata** (Partee, ter Meulen and Wall 1990). Here, we shall focus on **right-linear grammars** and **finite automata**.

A right-linear grammar produces simple trees containing **terminal** nodes and **non-**

**terminal** nodes, beginning from a starting non-terminal node, S. The non-terminal nodes form a sequence down the right-hand side of the tree, the pattern which motivates the term 'right-linear'.

An example is (1):



The particular tree in (1) would be produced by applying each rule of the following grammar once. Other trees can be produced in the grammar by applying some rules many times, others not at all, etc.

(2)  $G = \langle V_T, V_N, S, R \rangle$ , where

$V_T = \{a, b\}$ , a terminal alphabet

$V_N = \{S, A, B\}$ , a non-terminal alphabet

$S \in V_N$  is a non-terminal symbol,

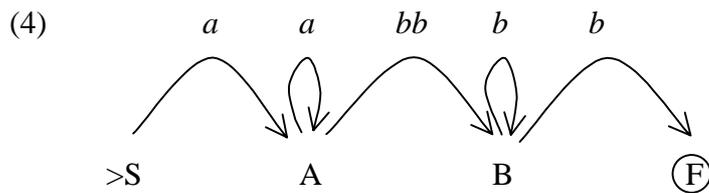
$R = \{S \rightarrow aA, A \rightarrow aA, A \rightarrow bbB, B \rightarrow bB, B \rightarrow b\}$ , a set of right-linear rules

The rules of a right-linear grammar consist of a non-terminal symbol to be rewritten either as a terminal string (e.g.  $B \rightarrow b$ ) or as a terminal string followed by a non-terminal symbol (e.g.

$A \rightarrow bbB$ ). The derivation of the terminal string  $aabbbb$  of tree (1) by applying each rule in turn is shown in (3):

$$(3) \quad S \Rightarrow aA \Rightarrow aaA \Rightarrow aabbB \Rightarrow aabbbB \Rightarrow aabbbb$$

Now compare the right-linear grammar with a finite automaton, illustrated in (4) by a **state diagram**, the positions S,A,B and F being the possible **states** of the system:



One can think of the finite automaton as being traversed along the direction of the arrows starting from the initial state S (marked by >), writing the lower-case symbols next to the arrows that are traversed, until the final state F (circled) is reached and a whole string has been generated. If we traverse each arrow once, for example, then a derivation will proceed from state S to state A, writing the symbol *a*, (a **transition** (S,*a*,A)), from state A to itself, writing another *a* (a transition (A,*a*,A)), and so on. In full, rendering at each stage of the derivation the symbols written (*as* and *bs*) with the state reached (S,A,B or F) marking the position at which any further symbols are to be written<sup>1</sup>, we have:

$$(5) \quad S \Rightarrow a_A \Rightarrow aa_A \Rightarrow aabb_B \Rightarrow aabbb_B \Rightarrow aabbbb_F$$

The similarity of this derivation to that of the right-linear grammar is substantial, (5) and (3) differing only in the presence or absence of the final 'F' which itself does no more than register

<sup>1</sup>By analogy to typing on a computer, the state symbol is in cursor position.

the termination of the derivation. A similar correspondence would obtain in the derivation of other strings by the two devices. This is because the analogy between the devices lies deeper than particular derivations - there is a structural analogy between non-terminal nodes and automata states, as suggested by the reuse of the labels 'S', 'A' and 'B'. Nodes and states are used to formulate the rules and transitions which respectively define the two kinds of grammar:

$$\begin{array}{lll}
 (6) & \text{rewrite rule} & \text{transition} \\
 & P \rightarrow xQ & \sim (P, x, Q) \\
 & P \rightarrow x & \sim (P, x, F)
 \end{array}$$

where:  $x$  is a string of terminal symbols;  $P, Q$  are non-terminal symbols or states other than the final state;  $F$  is a final state ( $F \neq P, Q$ )

Because the analogy (6) is general, it can easily be shown that for any given right-linear grammar a corresponding finite automaton generating the same language (i.e. set of strings) can be constructed, and vice versa. It follows that in general, the class of right-linear grammars and the class of finite automata generate the same class of languages, the **regular** languages - a class which, it is generally accepted, are less complex than natural languages. Because both devices generate this same class they are said to be of **equivalent generative capacity**. The point of interest is that this equivalence follows from the systematic structural correlation between right-linear grammars and automata summarised in (6). Finite automata and right-linear grammars are "**virtually isomorphic**" (Partee et al 1990:474) - "virtually" in that their structure differs only in the absence of an explicit counterpart in rewriting grammars for the final "F" state in an automaton, a minor and in this case inconsequential distinguishing mark. This *translation mapping* between right-linear grammars and finite automata is what makes their formal comparison explicit.

Having outlined the strong mathematical relationship between right-linear grammars and finite automata, we move on to discuss a comparison that is less well worked out: autosegments and prosodies.

### 1.1.2 Autosegments and Prosodies

It has often been said that Autosegmental Phonology (Goldsmith 1976) expresses an insight about phonological patterns that originates with the school of Prosodic Analysis (Firth 1948).<sup>2</sup> Goldsmith (1992) addresses the issue at greater length, proposing that, historically, the insights of Prosodic Analysis reached Generative Phonology via the field of African descriptive linguistics. After all, transfer of ideas directly from one school to another is unlikely when their interaction is more usually concerned with mutual criticism and distancing. The article prompted a reaction from Ogden and Local (1994), objecting that identifying prosodies with autosegments misrepresents the Firthian approach by viewing it through the conceptual lens of generative phonology. A response was given in Goldsmith (1994). What is lost in this series of papers is a scholarly *rendering* of the purported conservation of insight across the two approaches. An adequate rendering of the conservation of insight would be a *formal* matter, a mapping from representations of one kind to those of the other kind.

Goldsmith (1992) focusses part of his discussion on an example of vowel harmony in Igbo from Carnochan (1960). The segmental transcription (7) includes three vowels, all of which have retracted tongue root (marked by <sub>ɹ</sub>), while the latter two vowels are of identical quality. The prosodic analysis of Carnochan (1960) recognises five **phonematic units** A,C,I,r,ə, while phonetic continuity across them is analysed by two **prosodies**: L/R (for tongue root placement), y/w (for backness and roundness of vowels). Carnochan's representation is in (8), giving the

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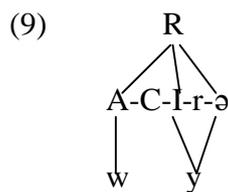
<sup>2</sup>E.g., Goldsmith (1976, 1979:203-4, 1990:3), Lass (1984:269), Anderson (1985:192-3), Kenstowicz (1994:311), Roca (1994:7), Bird (1995:10).

prosodic units  $y$  and  $w$  a notational treatment as predicates whose arguments are the phonematic units, enclosed in brackets. In turn, the prosodic unit  $R$  notationally takes as its argument all the other entities in the representation, enclosed in square brackets.

(7)  $\varnothing$  sɪrɪ 'he cooked'

(8)  $R[(A)w(CI r \emptyset)y]$

Drawing an analogy between the prosodic analysis and autosegmental analysis, Goldsmith (1992:157) offers an "autosegmental rewriting" of (8) with tiers and association lines:



Ogden and Local (1994), however, do not regard prosodies as something to be rewritten as autosegments, and set out to disentangle the two concepts. They contrast prosodic analysis with the movement down a derivational sequence of structures in autosegmental phonology, with any movement of information *from* phonematic units *to* prosodies, emphasising the static quality of expressions of prosodic analysis: "information is explicitly not ..'removed' or 'abstracted AWAY', and the phonematic units are not 'what is left'... are not 'sounds'... Phonematic and prosodic units serve to EXPRESS RELATIONSHIPS... All else that can be said about them depends on this most basic understanding." (Ogden and Local 1994:483)<sup>3</sup>. It is true that there are differences in why prosodies or autosegments are posited, how prosodies and autosegments are to be interpreted

<sup>3</sup>Prosodic analyst Allen, however, claims to "abstract the transition from the sequence as a whole" (Allen 1957:72), where "an incomplete prosodic analysis involves the allotment to phonematic units of data which in a complete analysis would be allotted to other prosodic units" (Allen 1957:70). This explicitly acknowledges the process of abstraction away from the phonematic sequence as an analytical procedure.

phonetically, how they interact with other aspects of the phonology and grammar, and whether or not they are given any language-universal significance. In autosegmental phonology, it is typical to have a skeletal tier consisting of X's devoid of interpretable content except as units of timing, with a universal set of phonological features farmed out to their own tiers, whether or not they express a syntagmatic relationship across timing slots. Tellingly, however, Itô (1986:65) provides an abbreviatory convention for laterality in Diola Fogy "in order to avoid irrelevant association lines" that is reminiscent of a prosodic approach:

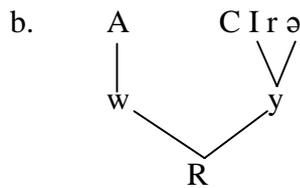
(10)            C V L C V  
                   | | \ / |  
                   s a t e    [salte] 'be dirty'

This is like opting not to set up a lateral prosody - since it expresses no relationship between different segments, but having a *t*-prosody over a phonematic sequence LC which is realised phonetically as [lt]. Similarly, *t* associated to a sequence NC is realised [nt].

Indeed, Goldsmith (1994:506) "doesn't buy" the apparent implication of Ogden and Local (1994) that there is no meaningful connection *at all* between autosegments and prosodies, and he questions the relevance of the objections to his actual goal: not a comparison of the theories, but a proposal on how insight is *indirectly* transferred from one theory to another. I submit that the relevance is in fact unavoidable. Unless there definitely is some insight that carries over, a proposal like Goldsmith's about how it was transferred is meaningless. We need to start mapping clearly between representations of the two kinds. Thus the prosodic representation (8), repeated here as (11a), maps to the autosegmental diagram in (11b) according to the mapping defined in (12).

---

(11) a. R[(A)w(CIrə)y]



(12) **A map  $M_{PA}$  from a prosodic representation to an autosegmental representation**

a. Primitive entities are mapped under identity.

e.g.  $A \rightarrow A$ ,  $r \rightarrow r$ ,  $w \rightarrow w$ , etc..

*This translates prosodic units to autosegments.*

b. Linear order is preserved.

*This translates each prosody into a tier of autosegmental structure.*

c. A predicate-argument relation is mapped to an association relation

$(\dots(\dots)Y\dots)X \rightarrow a(X,Y)$

*This translates prosody relationships into associations.*

Nested arguments are not mapped to associations on this formulation

e.g.  $R[.(A)\dots] \rightarrow a(R,A) \notin M_{PA}$       *R is not associated to A*

Carnochan's notation in (11a) implies a dependency relationship between the L/R prosody and the y/w prosody, and in (11b), the same dependency is expressed between autosegments in a planar autosegmental representation (Archangeli 1985 and Mester 1986 examine such dependencies between autosegments). Goldsmith's conversion into an autosegmental representation in (9) ignores the dependency relationship between L/R and y/w (for tongue root and roundness) immanent in Carnochan's representation, implicitly assuming that even if some prosodies are expressed most immediately over other prosodies, autosegments always associate directly to the central tier. This assumes a different translation to that in (12).

Describing and studying the properties of prosody-to-autosegment mappings, along the lines begun in this brief sketch, provides a formal comparison that would demonstrate a common insight between theories that are otherwise different. Goldsmith (1994:506) says that not all dialogue between prosodic analysis and other schools of thought will be carried out “in prosodic theory’s native tongue”, but formal comparison removes the need to understand one theory in terms of the other, because each theory is expressed in terms of mathematics.

### *1.1.3 Further Remarks*

Broe (1991) demonstrates how a prosodic analysis may be translated straight into the Unification Grammar formalism (Kay 1979) that lies behind contemporary non-derivational theories of grammar. Broe points out that the structural relation between Prosodic Analysis and Unification Grammar is explicable by a traceable historical influence, from Firth to Halliday to Kay. By contrast, the prosody-autosegment comparison traverses the divide between declarative and generative streams of linguistic research, but this does not mean that partial continuity is not real.

Despite the success in comparing right-linear grammars and finite automata, another comparison of two regular models, this time in phonology, lacks a straightforward structural analogy. Systems of ordered, regular rules (Johnson 1972) and systems of two-level rules (Koskeniemi 1983) are of equivalent generative capacity, but this has been shown by proving for each model separately the capacity to generate the class of regular relations (Kaplan and Kay 1994), rather than by mapping from one to the other. Karttunen (1993) constructs two-level-rule analyses for some particular examples previously analysed with ordered rules.

Alternative representational theories within the tradition of generative phonology have attracted some formal comparison. Waksler (1986) formally compares using Cs and Vs, or Xs, as the units of the skeletal tier. Zetterstrand (1996) formally compares a hierarchical model of vowel

height (nested organisation of height features) with an articulatory model (height features marking distinctions along a phonetic scale). Roca (1994) uses connections between representations in Government phonology and in mainstream generative phonology to open up a general basis for comparative evaluation of the theories, and Coleman (1995) also tabulates these connections. Coleman (1998) distinguishes the *names*, *forms* and *powers* of phonological representations and contends that some argumentation over notational systems for stress and meter is spurious because it turns on a difference of “name” rather than “form” – on presentation, rather than content.

The essence of formal theory comparison is the recognition of a mapping from one formalism to another that expresses their similarities. Examining *how* similar theories are is about examining how well-behaved the mappings are, a precise mode of comparison built on mathematics. If there is an isomorphism between the theories, they are none other than notational variants. If there is no isomorphism, the mapping still serves to provide an accurate analysis of the differences and any predictive consequences.

Since alternative theories come from different periods and/or different schools within the academic community, formal theory comparison may be viewed as a disciplined contribution to the history of linguistics, which in turn is motivated by the view that future theories benefit from understanding the past and building on the important insights (cf. Anderson 1985, Goldsmith and Huck 1995). There are many methodological, presentational and other theoretical issues that lend themselves to long-running dispute, but the advantage of a formal approach to theory comparison is the same as in Bloomfield's original contention that "the postulational method saves discussion, because it limits our statements to a defined terminology" (Bloomfield 1926[1957:26]).

## 1.2 Formal Comparison and Data-centred Comparison

Formal comparison contrasts with comparisons as to how well theories cope with any particular set of data.

### 1.2.1 Derivation and Optimisation as Descriptions of a Function

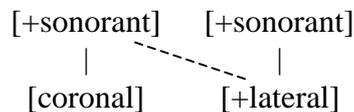
When we look at derivational and optimality-theoretic grammars for phonology, we find they have a similar outline insofar as they associate surface representational forms with underlying representational forms. What derivational theory and optimality theory do is provide two alternative descriptions of the function that maps underlying forms to surface forms..

Under derivational analysis (Halle 1962, Halle and Clements 1983), the phonological alternations found in a language are cast in terms of rules, each of which transforms one value to another in the relevant context. Thus if [X] alternates with [Y], then in order to formulate a rule we must decide whether [Y] derives from [X], or [X] from [Y]. If, for the sake of argument, [Y] arises regularly in a simply-defined context C, then it is suitable to derive it from [X] by means of a rule “X becomes Y in the context C”. In Klamath (Halle and Clements 1983:113), there are voiced, voiceless, and glottalised alveolar laterals, and there is a series of alternations involving laterals:

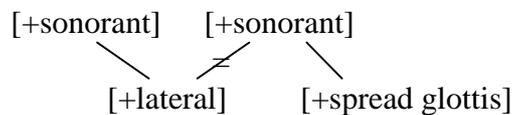
- |        |   |                                       |                                       |                        |
|--------|---|---------------------------------------|---------------------------------------|------------------------|
| (13)a. | $l_{\text{v}} \rightarrow lh$               | pal ɭa                                | [palha]                               | 'dries on'             |
|        | $l_{\text{v}}^? \rightarrow l^?_{\text{v}}$ | yalyal l <sup>ʔ</sup> i               | [yalyal <sup>ʔ</sup> a]               | 'clear'                |
| b.     | $nl \rightarrow ll$                         | hon li:na                             | [holli:na]                            | 'flies along the back' |
| c.     | $n_{\text{v}} \rightarrow lh$               | hon ɭy                                | [holhi]                               | 'flies into'           |
|        | $n_{\text{v}}^? \rightarrow l^?_{\text{v}}$ | hon l <sup>ʔ</sup> a:l <sup>ʔ</sup> a | [hol <sup>ʔ</sup> a:l <sup>ʔ</sup> a] | 'flies into the fire'  |

In (13a) the voiceless/glottalised laterals reduce under specific conditions - the presence of a preceding lateral. In (13b), the nasal becomes lateral under specific conditions - in assimilation to a following lateral. (13c) exhibits a combination of the two. We shall assume that the lateral segments have a [+lateral] feature, that voicelessness is given by the feature [+spread glottis] and glottalisation by the feature [+constricted glottis]. Then the Klamath pattern follows from the two rules in (14):

- (14) i. Spread [+lateral] leftwards onto another alveolar sonorant



- ii. Delink [+lateral] in the presence of [+spread glottis] or [+constricted glottis] if the [+lateral] is also linked elsewhere



In (13c), when an underlying nasal is positioned next to a voiceless or glottalised lateral, assimilation and reduction occur. This is captured if the reduction rule (14ii) may apply to the output of the lateral assimilation rule (14i). This leads to a **serial derivation**:

- (15)  $n_l^o$   
 $\downarrow$  (14i) leftward spread of [+lateral]: /n/ becomes /l/ preceding /l/  
 $l_l^o$   
 $\downarrow$  (14ii) right-side delinking of [+lateral]: /l/ becomes /h/ following /l/  
 lh

Although the second rule would not apply directly to the underlying representation /n<sub>l</sub><sup>o</sup>/, in (15) the first rule creates an intermediate representation to which the second rule does apply. The first

rule is said to **feed** the second rule in this case. The feeding of rules in series potentially leads to many intermediate representations, for the length of derivations is bounded only by the number of rules available. The interaction is also **opaque** in that the conditions under which assimilation occurs are taken away by reduction: /n/ changes to /l/ by assimilation to a following lateral, but the following segment is not lateral - it is /h/.

In optimality theory (Prince and Smolensky 1993, McCarthy 2002), phonological alternations depend on a hierarchy of constraints that require structures to observe certain requirements. A surface form may be selected from many possible **candidates**. Candidates may violate the constraints, but the surface form is the one which is **optimal** in that it violates the constraints minimally. Some constraints are **Markedness** constraints which discriminate against certain structures; other constraints are **Faithfulness** constraints which maintain identity between the underlying form and surface form. We formulate the following constraints that bear on the lateral alternations in Klamath:<sup>4</sup>

(16) i. OCP{sonorant}: *Adjacent sonorants are prohibited.*

(sonorant=[+sonorant,+consonantal])

ii. MAX([+lateral]): *All [+lateral] features in the input are preserved in the output.*

iii. MAX([+nasal]): *All [+nasal] features in the input are preserved in the output.*

iv. MAX(A): *All associations in the input are preserved in the output.*

v. DEP(A): *All associations in the output have a correspondent in the input.*

**Ranking:** OCP{son}, MAX([+lat]) >> MAX([+nas]), DEP(A), MAX(A)

---

<sup>4</sup> OCP{sonorant} reflects so-called 'sonority distancing' effects which exclude clusters of consonants of similar sonority. /nl/ is excluded in other languages, including English, Latin and Toba Batak (Calabrese 1995:424). Faithfulness constraints which refer to feature values [+F]/[-F] are adopted in line with Inkelas (1994), and are used again in chapter six. That voiceless and glottalised laterals are specially permitted in the Klamath inventory is

The Klamath pattern follows when the constraints are ranked as in (16). Nasality, and the original format of associations, are sacrificed in preference for the retention of laterals but the avoidance of nasal-lateral sequences. This is represented on a **tableau** in (17):

(17)

/n̩/	OCP {sonorant}	MAX ([+lateral])	MAX ([+nasal])	DEP (A)	MAX (A)
n̩	*!				
l̩	*!		*	*	
 lh			*	*	*
nh		*!			*

The optimal candidate is indicated by a pointed finger (). It violates three of the faithfulness constraints given, indicating the extent to which it differs from the underlying form /n̩/, violations being represented by marks (\*) in the respective cells. Alternative candidates, however, violate higher-ranked constraints. These **crucial violations** determine that the candidates are suboptimal and are indicated in the tableau by exclamation marks (\*!), and areas of the tableau that are no longer relevant to sifting the crucial violations are shaded off. An exhaustive analysis of optimality would demonstrate other crucial violations for any number of other conceivable candidates.

In both analyses, the nature of phonological representations and the identity of surface forms is the same. And there is often broad agreement about this. Both theories attempt to derive the same bare facts of distribution-and-alternation patterns in sounds, and there is broad

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attributable to the ranking of faithfulness constraints MAX[+lateral], MAX([+spread glottis]), MAX([+constricted glottis]) over markedness constraints \*[+sonorant,+spread glottis] and \*[+sonorant,+constricted glottis].

agreement that derivational systems and optimality systems should impose the predictable aspects of phonological structure, with the characteristics of particular words encoded in the lexicon.<sup>5</sup> These patterns are expressed through segmental units, features, syllable and foot structure, units of timing, weight and accent, and domains such as word, stem or phrase. Some disputes exist, and it is conceivable that consensus on the representational theory may change with the advent of optimality theory, but the two approaches are not tied to distinct representational theories. Where necessary, we assume that phonological representations follow accepted norms of autosegmental phonology (Goldsmith 1976, Bird 1995).

### 1.2.2 Describing Functions

Optimisation with respect to constraints and derivation by rules each express the function that maps /n/ to [lh] in Klamath. Alternative descriptions of a function are not unheard of. Thus, the numerical function in (18a) may be given either of the two descriptions (18b) or (18c).

- (18) a.  $1 \mapsto 4, 2 \mapsto 6, 3 \mapsto 8, 4 \mapsto 10, 5 \mapsto 12, \dots$   
 b.  $f(n) = 2n + 2$   
 c.  $f(n) = 2(n + 1)$

In this case, the factorisation into '2' and 'n+1' in (18c) is more highly valued mathematically since the factored expression is more abstract. But if a function from underlying phonological

---

<sup>5</sup> In optimality theory, lexical forms are determined uniquely by the principle of Lexicon Optimisation (Prince and Smolensky 1993:193), by which the lexical form is the one which leads to the minimum possible violations of constraints by the eventual surface form. And in derivational theory, lexical forms are determined by the Derivational Simplicity Criterion (Kiparsky 1982:148): "Among alternative maximally simple grammars, select the one that has the shortest derivations". These conceptually similar principles both tend to make lexical forms as similar as possible to the actual surface alternants, and tend to exclude features from the structure that are never realised in any alternant, unless there is good reason otherwise. However, different issues may arise in the detailed implementation of these two principles (see Archangeli and Suzuki 1997).

representations to surface phonological representations can be described in two different ways, then is the difference simply a matter of presentation, or are the grammars of derivational theory and optimality theory different in any deeper sense? We can consider this question from the angles of applied mathematics, pure mathematics, and mathematical logic.

From a perspective of applied mathematics, Bromberger and Halle (1997) envisage that, of the two phonological theories, one is a deeper description than the other. They claim:

the fact that creative and gifted linguists have come up with tableaux should eventually turn out to rest on aesthetically intriguing, but ultimately accidental epiphenomena that need to be explained but that have little if any explanatory depth themselves. One can think of analogies in other disciplines. So, for instance, the predictive power of the laws of geometric optics is explainable ultimately in terms of the mechanisms and laws of the wave theory of light, but not vice versa. (Bromberger and Halle 1997:119)

Geometric optics derives from wave theory mathematically, and if in the same way the predictive power of either derivational theory or optimality theory is explainable in terms of the other, this should be clear from a formal study. However, other interrelationships are conceivable. Two theories can provide unified but complementary insights about the nature of the function. The wave theory of light and the quantum theory of light are essentially different conceptions of light, yet both are found to be necessary to describe known light behaviour and mathematical connections between the two have been made by De Broglie, Dirac, Schrödinger and others.

In pure mathematics, unification between superficially different areas of mathematics is seen as desirable for shedding new light on those domains (the Langlands programme, Gelbart 1984). In our case, optimality theory draws on the mathematical area of optimisation, and optimal solutions to problems can sometimes be solved by ‘path methods’. One might then imagine that derivational theory describes the paths to the outcome that is considered optimal, connecting the two theories together. As it turns out, this will fall down at the level of detail when we observe later that derivations by some phonological rules overshoot and undershoot the outcomes that would be considered optimal, making this analogy somewhat soft.

When it comes to mathematical logic, Chomsky (1975) has noted that derivational rewriting systems in linguistics correspond to the logic of production systems, while Bird (1995:24) makes the reasonable suggestion that optimality theory is based on a non-monotonic logic of conflict-resolution (Ginsberg 1987). A difference of logic suggests that an abstract unification will not be possible, and that however much the theories coincide in their effects, correlations between them will not adhere to any rigid properties and will be explainable only in functional terms by the fact that it happens that they are being called upon to derive the same outputs. Our results will support this view.

### *1.2.3 From Data to Grammars*

Working on this level switches the matter to be investigated from data to grammars. This meets an ambition for generative grammar:

Linguists must be concerned with the problem of determining the fundamental underlying properties of successful grammars. The ultimate outcome of these investigations should be a theory of linguistic structure in which the descriptive devices utilized in particular grammars are presented and studied abstractly, with no specific reference to particular languages. (Chomsky 1957:11)

If studies of patterns in a data corpus bring about statements of *what* speakers know about their language, the study of hypotheses about grammar design focuses more directly on *how* speakers know what they know about language. The Minimalist Program (Chomsky 1995), for example, attempts to do linguistics on this level, forming proposals on the design of grammars from the conceptual base of ‘minimalism’. Reviewing Chomsky (1995), Freidin (1997:572) observes

Chapter 4 focusses on very broad and abstract conjectures about language design and the theoretical constructs that account for it. Where most of the numbered examples in chapters 1-3 contain linguistic expressions from some particular language, those of chapter 4 deal mostly with definitions, questions, conjectures, assumptions, abstract structures, lists of relevant topics or properties of constructions, and of course, various principles, conditions, guidelines, and just plain stipulations - less than half cite linguistic expressions. ... Thus chapter 4 ... eschews detailed analyses of linguistic data.

Freidin warns that this style of reasoning may be “rather alien and difficult to deal with, primarily

because before the advent of the minimalist program most research in the field has been data-driven” (Freidin 1997:573).

Formal comparison of the derivational and optimality theoretic descriptions of the underlying-to-surface function of phonology compares alternative grammar designs. In a data-centred comparison, theories may be compared by their ability to provide a natural analysis of some piece of data, but this does not offer any one particular response to the analytical problems that may be encountered. Concerning a collection of empirical studies that compare optimality theory with derivational theory over particularly interesting data, Roca (1997b:9) observes, “different writers respond differently to the challenge, some purposely turning their backs on the theory, while others endeavor to modify it to achieve compatibility with the data.” Thus, Blevins (1997) proposes a system in which repeated optimisations may be interspersed with traditional phonological rules; Archangeli and Suzuki (1997) propose to extend optimality theory with new varieties of constraints; others (Clements 1997, Rubach 1997) propose that surface forms are derived from a minimal series of optimisations. It is possible to show temporary support for one system over another in reference to some language fragment, but this approach does not grasp in any *general* sense the conservation of insight or divergence of insight across theoretical boundaries or what should be done to resolve the difficulties. Formal comparison can meet this challenge, specifically examining the structural differences between alternative grammar designs in order to generate the most general solutions to the problem of descriptive coverage in phonology.

### 1.3 Formal Comparison and Substantive Comparisons

Form and substance are interlocked. The former is used to express the latter. Linguistic theory seeks to pursue that which is universal to language along these parallel lines:

A theory of *substantive universals* claims that items of a particular kind in any language must be drawn from a fixed class of items. (Chomsky 1965:28)  
 ...*formal universals* involve rather the character of the rules that appear in grammars and the ways in which they can be interconnected. (Chomsky 1965:29)

Comparing theories along both lines may be of considerable interest. However, a comparison of formal universals compares at a deeper, more abstract level.

#### 1.3.1 Substantive Universals in Derivational and Optimality Theory

In optimality theory, a strong theory of substantive universals is attempted: “U[niversal] G[rammar] provides a set of constraints that are universally present in all grammars... a grammar is a ranking of the constraint set” (McCarthy and Prince 1994:336) - this being a maximally simple null hypothesis (McCarthy 2002:11). A looser conception might have the constraint set as an open system, capable of absorbing constraints that amount to knowledge about phonetic complexity (Myers 1997b) and idiosyncratic facts of particular languages (Bolognesi 1996, Hayes 1999, Moreton 1999). The commitment to substantive universals has particular consequences for analysis under optimality theory:

Positing a new constraint is not to be undertaken lightly. Constraints in OT are not merely solutions to language-particular problems; they are claims about UG [Universal Grammar] with rich typological consequences. ... Descriptive universals rarely make good constraints, but descriptive *tendencies* often do. Indeed, the success of OT in incorporating phonetic or functional generalizations is largely a consequence of its ability to give a fully formal status to the otherwise fuzzy notion of a cross-linguistic tendency. (McCarthy 2002:39-40)

Thus, the particular claim that all languages have the constraint ONSET “syllables have onsets” (Prince and Smolensky 1993), is established to the extent that there is a preponderance of onset-filled syllables in language such that each language either has onsets in all syllables, or has onsets

in every syllable other than those specifically for which a conflicting requirement holds sway – in which case another constraint is ranked higher.

In derivational theory, it has been proposed that parameters delimit the range of possible rules, for stress (Hayes 1995, Halle and Idsardi 1995), and for the distribution of features paradigmatically and syntagmatically (Archangeli and Pulleyblank 1994, Calabrese 1995). Most syllabification rules fall within some simple universal principles and parameters (Roca 1994).

It is desirable to compare the typological consequences of substantive universals in derivational theory and optimality theory. However, theories have consequences only to the extent that they are *formalised*. The precise consequences of putative universal constraints follow from a theory of constraint form and from the minimal conditions under which constraints may be violated. Similarly, the consequences of putative parametric rules follow from a theory of the formal structure of rules and a theory of the interaction between rules from which serial derivations are constructed.

### *1.3.2 Formal Universals in Derivational and Optimality Theory*

In derivational phonology, the classical formal proposal is that grammars subject rules to rule ordering constraints 'R<sub>A</sub> is ordered before R<sub>B</sub>' which regularise the sequence of application. Then, in principle, a rule may create the conditions for another rule to apply (a *feeding* effect), although a rule may fail to apply when another rule creates the conditions for its application (a *counterfeeding* effect); one rule may wipe out the condition for another rule before the other can apply (a *bleeding* effect); or, the rule whose conditions would be wiped out by another rule may be allowed to apply first (a *counterbleeding* effect). Alongside rule ordering, or in place of it, other principles of application have been tried (see Bromberger and Halle 1989, Pullum 1979). It is a moot point whether ordering statements may be replaced by other principles in all cases (Iverson 1995), but the sufficiency of ordering makes it a null hypothesis, sometimes seen as a

standard proposition (Bromberger and Halle 1989:58).

In optimality theory, constraints must be well-defined so as to assign a particular number of violation marks to each candidate, and are violated in just the way predicted by the theory - minimally, when in conflict with higher-ranked constraints (Prince and Smolensky 1993). In some cases there is evidence that constraint interrelationships other than ranking are needed (Kirchner 1996, Smolensky 1997). Since the core of the theory employs Markedness constraints and Faithfulness constraints (as set out in 1.2.1 above), any other constraint types would require a careful defence. Processes arise from adherence to markedness constraints at the expense of faithfulness to underlying forms. It has been argued that the formal universals of optimality theory enable a natural analysis of ‘conspiracies’, whereby different processes achieve the same output generalisation. In OshiKwanyama, a western Bantu language cited in Kager (1999:83), there are no sequences of nasal plus voiceless obstruent. Roots with nasal-final prefixes show nasal substitution, whereby a voiceless obstruent is replaced by a nasal with the same place of articulation (19a); but loanwords exhibit post-nasal voicing (19b). Both of these processes serve the constraint \*NC<sub>0</sub>: “No sequences of nasal plus voiceless obstruent”.

- |      |    |            |         |                    |
|------|----|------------|---------|--------------------|
| (19) | a. | /e:N-pati/ | e:mati  | ‘ribs’             |
|      |    | /oN-pote/  | omote   | ‘good-for-nothing’ |
|      |    | /oN-tana/  | onana   | ‘calf’             |
|      | b. |            | sitamba | ‘stamp’            |
|      |    |            | pelanda | ‘print’            |
|      |    |            | oinga   | ‘ink’              |

In a rule-based analysis, the NC<sub>0</sub> configuration would be expressed twice - once in a post-nasal voicing rule, once in a morphophonemic nasal substitution rule. In an optimality analysis,

however, both processes follow from the single constraint \*NC<sub>◦</sub> interacting in different ways within a single hierarchy of constraints:

(20) (Kager 1999:86)

	ROOTLINEARITY	*NC <sub>◦</sub>	IDENT(Voice)	LINEARITY
/e:N <sub>1</sub> -p <sub>2</sub> ati/				
☞ e:m <sub>1,2</sub> ati				*
e:m <sub>1</sub> b <sub>2</sub> ati			*!	
e:m <sub>1</sub> p <sub>2</sub> ati		*!		
/sitam <sub>1</sub> p <sub>2</sub> a/				
sitam <sub>1,2</sub> a	*!			*
☞ sitam <sub>1</sub> b <sub>2</sub> a			*	
sitam <sub>1</sub> p <sub>2</sub> a		*!		

So the two formalisms differ in whether multiple effects follow from one statement of an affected configuration, or whether repeated statements of the configuration are needed. This exhibits a difference in *elegance* of description of the phonological function, but a more drastic possibility is when effects in one theory are not even expressible in the other theory. For example, Roca (1997b:8) has claimed that "the derivational effects of counterfeeding and counterbleeding relations are mathematically inexpressible in Optimality Theory", delineating a general issue for the theories, as McCarthy (1999b:268) observes. We will explore in coming chapters conditions under which effects in one system are or are not replicated in the other.

In conclusion, optimality theory purports to express new substantive insights precisely because it offers a revised view of the formal universals of grammar. Comparison of the formal

universals of optimality theory with those of derivational theory compares at a more fundamental level.

#### **1.4 Form and Semantics**

A comparison of form contrasts with comparisons based on a semantics formulated for the two theoretical approaches.

The formal study of the structure of phonological representations and how their properties are derived has continued productively in the absence of a well-worked-out understanding of exactly what phonological symbols refer to, but phonology has always selected among three sources for its meaning: phonetics, psychology, or mathematics. Phonological symbols can make sense phonetically in terms of the articulatory movements made during speech and their targets on the articulatory tract (Myers 1997b) or the neural commands to execute these movements (Halle 1983), yet it has long been recognised that phonological units have a psychological reality that may not always be present in the phonetic execution (Sapir 1933). We might also view phonology as mathematics, either as a default option when we are unsure of the precise interpretation of phonology in the real world (Twaddell 1935), or as a kind of base from which to map to human speech (Bird 1995) or to the human mind.

Bromberger and Halle (1997) formulate a semantics for phonological symbols in which they refer to events in the mind of the speaker. Their approach leads to slightly different formulations for derivational theory or optimality theory - that is, phonological symbols like 'k' and '[+round]' mean slightly different things in the two theories. They then compare the two theories on this basis. Such a study shares a broad motivation with this one to go beyond the din of detailed controversies to explore the very nature of the theories. In this section, we review their work, and contrast it with the approach taken in this thesis.

### 1.4.1 Bromberger and Halle (1997)

Bromberger and Halle (1997) - hereafter B&H - develop their semantics of phonological symbols from three initial assumptions, defended at length:

#### (21) Assumptions for a Semantics of Phonology

- (i) that phonological symbols stand for predicates,
- (ii) that within any theoretical approach, each symbol stands for the same predicate in all contexts, and
- (iii) the predicates purport to be true of events in the real world of space and time.

That is, just as a natural language predicate *'hot'* may be true of just-cooked foods, fires, and the air in regions heated by the sun, so phonological symbols such as *'k'* and *'[+round]'* make up a language that is supposed to describe in unambiguous terms events in the lives of speaker-hearers exercising their linguistic capabilities at particular times in particular places. This clearly eschews any mathematical view of the meaning of phonology. It also, as B&H show, ultimately excludes the possibility that phonological representations refer to the articulatory gymnastics of phonetic utterances. The so-called surface representation might be given this interpretation, but more abstract representations (those at earlier stages of derivations, or the inputs and candidates on tableaux) cannot be interpreted this way. The requirement that phonological symbols have the same meaning in all instances (assumption (ii).) rules out a phonetic interpretation. Still assuming that phonological symbols refer to real-world events (assumption (iii).), theories like derivational theory and optimality theory warrant a semantics in which phonological symbols refer to events in the *mind/brain* of a speaker-hearer, claiming that there are several events in the mind of a speaker as the form of an utterance is being formulated.

B&H offer the sentence (22a) for consideration. IPA transcription is given in (22b).

- (22) a. “Canadians live in houses” - uttered by Sylvain Bromberger (S.B.) in  
Colchester, at about 3pm, 1st September 1995
- b. kəneɪdɪənzlɪvɪnhauzəz

The first segment [k], for example, is a conjunction of the articulatory features [dorsal], [-continuant], [-voice] and [-nasal]. Disseminating B&H's succinct formulae, the semantic interpretation of this is that 'k', or equivalently each of the features, purports to be true of a stage of S.B.'s life when he had the intention to perform the articulatory gymnastics specified by those features. Just prior to an utterance, there is an *intention* by the speaker, an event in his mind, to make certain articulations. The intention to perform a voiceless velar plosive is an event satisfied by the predicate represented by the symbol “k”. Such an event is distinct from the physical utterance itself, so phonological predicates may also be satisfied at other times when a speaker intends to articulate but no articulation is physically carried out, though the physical utterance is the outward evidence that the mental events have occurred.

As it happens, the features of the first segment [k] in (22b) do not alternate in the course of the derivation. Other features in the underlying form may change. The morpho-phonological alternation *Canada/Canadian* [kænədə kəneɪdɪən] leads to an analysis in which the first vowel is underlyingly ‘æ’ at the first stage of the derivation, but is ‘ə’ at later stages of the derivation. Since an utterance of sentence (22) does not use the ‘æ’, B&H conclude that the event by which the predicate ‘æ’ is satisfied is one in which the speaker *intended to perform the articulatory features of ‘æ’ unless precluded by some rule*. In the corresponding optimality analysis, since the vowel is underlyingly ‘æ’ at the input level, but ‘ə’ at the output level, the event which satisfies the predicate ‘æ’ is one in which the speaker *intended to perform the articulatory features of ‘æ’*

*unless not optimal*. This means that the predicates have different satisfaction conditions in the two theoretical approaches. Given that symbols refer to intentions to perform particular articulatory gymnastics, the ways that the intentions are hedged are different.

From these semantics, laws predicting the linguistic behaviour of speakers - that is, their employment of their internalised grammar - can be postulated. The linguistic behaviour predicted by derivational theory on this view is summarised in (23).

(23) Derivational Theory

stage in speaker's timeline	predicates to be satisfied
1	<u>k</u> æ...
2	<u>k</u> æ...
	...
<i>k</i>	<u>k</u> ə...
	...
<i>n</i>	<u>k</u> ə...

Speakers at one stage intend to perform the complex of features of the first line of the derivation unless any is precluded by some rule(s), then at a following stage they intend to perform the complex of features of the second line of the derivation unless any is precluded by some rule(s), and so on with stages for all lines in the derivation. At some stage *k*, the intention to produce in the second segmental position the 'ə' vowel unless precluded by some rule(s) would replace the intention to produce the 'æ' vowel unless precluded by some rule(s), because of the application of vowel reduction. Likewise, optimality theory predicts a certain output stage that must follow a certain input stage as in (24): the features specified in the input line would be predicated of an

initial stage where S.B. intended to perform them unless they were not optimal, and the features specified by the optimal candidate would be predicated of a final stage where S.B. intended to perform them, vacuously unless not optimal.

(24) Optimality Theory

stage in speaker's timeline	predicates to be satisfied
input	<u>kæ</u> ...
output	<u>kə</u> ...

So, within derivational theory, there will be a sequence of stages that must be gone through when making an utterance like "Canadians live in houses" - the stages of the derivation, and within optimality theory, an input event must be superseded by a certain output event. In this way, the two theories present alternative claims as to what the mental events are that lead to the articulatory intentions that are actually used in utterances.

*1.4.2 Assumptions: A Critique*

Having shown how the three assumptions in (21) lead to different semantics for phonological symbols in the derivational theory and the optimality theory, B&H go on to argue that, given the choice, the derivational theory is significantly more explanatory than optimality theory, since although either approach can in principle explain why phonological representations are the way they are, only the laws of derivational theory explain (or explain in a simple way) what sequence of stages are gone through in the mind of the speaker to convert an underlying form into the surface form. The crucial question is whether the assumptions made by B&H that suggest such far-reaching conclusions can be sustained. B&H themselves "think that these assumptions are unproblematic and, in principle at least, widely accepted. But since they are

seldom openly stated, and are often disregarded in practice, they may be more controversial than we think.” (B&H 1997:95). They also suggest that the debate between the two theories “won't ever be settled cleanly until and unless we become more explicit about the validity of these non-empirical considerations and, in particular, about their consequences for the meaning each theory implicitly assigns to the phonological symbols they both share.” (B&H 1997:121)

The first assumption, that phonological symbols stand for predicates, seems the least likely to be problematic. Bird (1995), despite operating from a different theoretical and semantical standpoint (declarativism), agrees that phonological symbols are predicates, providing an axiomatisation of phonology in terms of predicate logic.

The third assumption, that phonology is about events in the minds of speakers at particular times, will mean that a system that determines surface representations from underlying representations will inevitably be tied to the production of correct articulatory sequences for utterance from memorised forms. The wisdom of this is not clear, in the sense that production of the form of an utterance is just one of the tasks of a language user. Furthermore, B&H's view of linguistic theories as accounts of mental events at the time of production, rather than as characterisations of the knowledge of the speaker, is at variance with accepted goals of grammatical theory, as McCarthy (1999b) has also commented. Thus:

It is not incumbent upon a grammar to compute, as Chomsky has emphasized repeatedly over the years. A grammar is a function that assigns structural descriptions to sentences; what matters formally is that the function is well defined... one is not free to impose arbitrary additional meta-constraints (e.g. 'computational plausibility') which could conflict with the well-defined basic goals of the enterprise. (Prince and Smolensky 1993:197)

When we say that a sentence has a certain derivation with respect to a particular generative grammar, we say nothing about how the speaker or hearer might proceed, in some practical or efficient way, to construct such a derivation. (Chomsky 1965:9)

In practice, a production semantics is not compatible with derivational models of generative grammar as a whole (Halle and Marantz 1994, Chomsky 1995) of which generative phonology is supposed to be a part. The logically most primitive level is entirely abstract and sound-meaning pairings are generated as output. A linguistics with a production semantics would differ from this, since it would go from intended meaning to the intended collection of articulatory gymnastics which conveys the meaning. Like derivational theory, Optimality Theory also explicitly deviates from amenability to a production bias:

[Our] focus shifts away from the effort to construct an algorithm that assembles the correct structure piece by piece, an effort that we believe is doomed to severe explanatory shortcomings. Linguistic theory, properly conceived, simply has little to say about such constructional algorithms, which (we claim) are no more than implementations of grammatical results in a particular computation-like framework. (Prince and Smolensky 1993:20)

We turn finally to B&H's second assumption, that within any theoretical approach, each symbol stands for the same predicate in all contexts. If each symbol always stands for the same predicate, then again, they must refer to one task that language users undertake. The assumption that phonological symbols stands for one and only one predicate implies that phonology has nothing to say about perception, acquisition, or memory - only production.<sup>6</sup> This is different from

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<sup>6</sup> B&H argue that derivational theory and not optimality theory provides an explanatory account of production, supplying a simple sequence of stages traversed by the speaker in deriving the form to be executed. But it can work the other way: parallel research argues that optimality theory supplies superior accounts of language acquisition. Pulleyblank and Turkel (1997) show how the optimality framework is intrinsically suited to the task of learning grammars, avoiding learnability 'traps' that pose problems for the learning of parametric and rule-based grammars. Myers (1997b) shows that optimality theory but not rule-based theory enables phonetically natural phonological generalisations, of which there are many, to be acquired systematically, since a learner may incorporate constraints of the form 'X is difficult to articulate' and 'X is difficult to discriminate' directly into grammar from knowledge of his/her physiological and auditory limitations.

our wider, preformal considerations of phonology, the relevant points of which are found in Bromberger and Halle (1989:53):

Phonology... is primarily concerned with the connections between surface forms that can serve as input to our articulatory machinery (and to our auditory system) and the abstract underlying forms in which words are stored in memory. Whereas syntax is concerned with the relations among representations that encode different types of information requiring different types of notation, phonology is concerned with the relationship between representations that encode the same type of information - phonetic information - but do so in ways that serve distinct functions: articulation and audition, on the one hand, and memory, on the other. ...underlying phonological representations of words are stored in speakers' permanent memory, whereas phonetic surface representations are generated only when a word figures in an actual utterance

Underlying representations, but not surface representations, have as a domain of interpretation the brain's memory storage, while surface representations are themselves systematically ambiguous semantically between instantiation in the speaker, and in a hearer, around the time of an utterance. The interesting thing about phonology is precisely that the same phonological notation refers to all these contexts, each of which places a different real-world interpretation on that notation. *Phonology is, in essence, systematically ambiguous.*

One might instead make the softer claim that phonological symbols stand for the same predicates at least *within a given derivation*. This is quite natural, since formally, members of a derivational sequence form a common grouping (the form of sequences is studied in chapter five). It is less natural to require semantic unambiguity for both an *input* and *output* to a tableau, since formally the two have essentially different roles. It is odd that the input should be a predicate that is satisfied if a speaker intended to perform-certain-articulatory-gymnastics-unless-not-optimal when the input, coming before the output, is in principle not articulable. By contrast, members of derivations are articulable in principle, since the derivation terminates after some arbitrary number of steps. In this sense, a semantics formulated on an assumption of unambiguous satisfaction conditions is not even-handed between the two theories: it serves derivations. Of course, as noted by B&H (1997:119-121), derivations in optimality theory might be constructed, say, by the algorithms of Tesar (1995,1996) which converge on the optimal form

in successive stages by a dynamic search process. In this case, phonological predicates defined by optimality theory could be satisfied at these successive stages by intentions to perform-certain-articulatory-gymnastics-unless-not-optimal in the analogous way to rule-based derivations.<sup>7</sup>

In one particular context, B&H themselves effectively abandon the assumption that symbols are unambiguous. At the end stage, they claim, two kinds of predicates are satisfied simultaneously: those in which the articulatory intentions are hedged by unless clauses (“phonological” predicates), and those in which the articulatory intentions are uncomplicated, with no unless-clauses (“phonetic” predicates):

...any stage that satisfies the predicate of first line of the derivation motivates (in the DT sense) a stage that satisfies the predicate of the last line (and thus is a stage that does not motivate further stages) and that *also* satisfies the ‘corresponding’ *phonetic* predicate...  
 ...any stage that satisfies the predicate of the input of the tableau motivates a stage that satisfies the predicate of the winner and that *also* satisfies the ‘corresponding’ *phonetic* predicate...  
 (B&H:116)

Although the members of a derivation form a common grouping, the final form is distinctive in that it is the form which may actually be executed. The satisfaction of the phonetic predicates by an intention in the speaker’s mind seems justified by work of Lenneberg which shows that: "The neural paths to the various articulators being of different lengths, instructions to move them must leave the brain at different times thus requiring that the effect be "intended" before being accomplished." (B&H 1997:102) However, making a stage systematically ambiguous in this way is a curious redundancy,<sup>8</sup> and a more obvious scenario would be that the phonetic predicates are

<sup>7</sup> Bromberger and Halle argue that Tesar algorithms are more complex and *prima facie* less plausible than the rule-driven alternative, eclipsing any misgivings about intermediate stages in rule-based derivations (Goldsmith 1993:6, Lakoff 1993:117, but cf. Clements 2000).

<sup>8</sup> Claiming that phonetic predicates are satisfied with phonological predicates simultaneously at the end of the phonology implies that cognitive processing has already determined by that point in time that no more rules are going to apply. If so, a hedged intention is redundant. B&H say nothing about this doubling, which is unfortunate, because their argument that the theories are in conflict depends on it. The conflict between the theories is based on the view that either theory is causally sufficient to motivate a stage at which the phonetic predicates are satisfied. As it stands, the contention that derivational-theory predicates and optimality-theory predicates are not both satisfied together hinges on the contention that each theory’s predicates and the phonetic predicates *are* both satisfied together, shifting rather than solving the problem.

satisfied at a stage *after* the phonological derivation has settled at a final stage. Nevertheless, the systematic semantic ambiguity of the representation determined by the grammar as the surface form is also understandable from its particular formal status as the set of final forms in derivations / tableau outputs (as examined in 2.1.1), and it is after all often specially marked notationally by enclosing the phonological symbols in square brackets, [...].

In these latter observations, the *formal* role of phonological expressions tends to decide the extent to which *interpretations* may vary, whether as members of a derivation, as inputs and outputs of a tableau, or as the surface form. This makes the formalism itself more basic.

#### 1.4.3 From Semantics To Syntax

The semantics of phonology is what its expressions are true of. Its syntax is concerned with how representational structures are built up from primitive units, and with how the underlying representations are connected to the surface representations - the formation of the derivations, or optimisations, or whatever. Partee, ter Meulen and Wall (1990:199) point out that inquiries into the syntax and semantics of formal systems are complementary, addressing different questions<sup>9</sup>. This means, for example, that two systems may have disparate domains of interpretation yet have a structural similarity, or they may have convergent semantic domains yet be structurally rather different.

B&H observe that the semantic difference they construct between derivational theory and optimality theory reflects a general situation in science studied by philosophers such as Kuhn where two theories are “incommensurable” because although their predicates are partially

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<sup>9</sup> The syntax/semantics distinction came to light in the history of mathematics when it was shown that the assumptions of Euclid’s classical geometry could be modified and still give a consistent system. Euclidean geometry has it that given a line L and a point P not on L, there is exactly one line through P that runs parallel to L and never meets L. But, counterintuitively, we may assume without internal contradiction either that there is *no* line through P parallel to L, or that there is *more* than one. Euclidean geometry, then, is not ‘intrinsically’ true, but rather is true *of* some *domain*. In fact, Euclidean geometry is true of planes or flat surfaces, while non-Euclidean geometry is true of curved surfaces (Partee, ter Meulen and Wall 1990:87ff).

similar, there is a subtle shift. The phonological predicates in derivational theory and optimality theory are both satisfied by articulatory intentions in the mind of a speaker, but with different unless-clauses attached.

In this thesis we will show that the syntaxes imposed by derivational theory and optimality theory are also partially convergent, in their own way. On either theory, a surface representation is different from the underlying representation in specific ways, and identical in all other specific ways. The systems that bring about this state of affairs seem analogous on several levels but do not converge in any rigid sense and eventually break down in potentially interesting ways.

The advantage of the comparison of form over the comparison of semantics is that it is concerned with essentials of the working of each framework, and is not embroiled in the problems we have recognised surrounding the semantics developed by Bromberger and Halle (1997). Consequently, any (correct) results of a comparison of form will be stronger and their consequences decisive. Coleman and Local (1991) make essentially the same point: concerning the validity of the “no-crossing constraint” in autosegmental phonology, they argue that their conclusions, based on the syntax of autosegmental representations, are stronger than conclusions based on some semantic interpretation of autosegmental representations (Sagey 1988, Hammond 1988), because agreement on the semantics of phonological expressions is lacking.

## 1.5 Conclusion

In this chapter, formal theory comparison has been introduced and motivated in the light of a number of points. Specifically,

- Exposing the inadequacy of a theory by comparison with another can lead to a better theory, in some cases by formally integrating the two.
- Formal theory comparison is confined to defined terms, saving interminable discussion of other controversial issues.
- Comparison of alternative descriptions of grammar is fully general and systematic, unlike comparisons of alternative descriptions of data.
- Comparison of alternative formal universals operates at a level which underlies any substantive results.
- Results of formal theory comparison are stronger than comparisons based on a semantic interpretation of the theories, whose bearing depends on the acceptance of the particular interpretation.

There are a few precedents of formal comparison in linguistics, and it stands as a general approach awaiting application to theoretical controversies. It is, of course, but one means of achieving excellence in linguistics. Other scholarly requirements, including the search for pertinent data, generating typological predictions, disciplined techniques of field work and laboratory work, analytical creativity, philosophical investigations, etc. should be supplemented, certainly not displaced, by an increased formal understanding of putative grammatical systems which the complexity of the subject demands.

2:

## **SPECIFYING THE FRAMEWORKS:**

### **GENERATION VERSUS EVALUATION**

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In 1.2, it was observed that both derivational and optimality frameworks spawn grammars that describe a function from underlying forms to surface forms. In order to develop a formal comparison of the two theoretical frameworks, we must specify how each constructs this function so we can look for structural correlates between the two.

As pointed out by Archangeli and Langendoen (1997:ix), there are two broad formal strategies that inform these frameworks, **generation** and **evaluation**. Generation involves the use of operations that modify (change or add to) given structures, evaluation involves measuring the extent to which given structures comply or fail to comply with constraints. The core of the derivational framework involves generation by a series of rules, the core of the optimality framework involves evaluation by constraints which are ranked to resolve any conflicts. We shall argue here that it will not do to compare Optimality-Theoretic constraint evaluation with the work of constraints in rule systems, since constraint evaluation is an additional development to the core devices of the derivational framework. Similarly, it will not do to compare rules with the Generator function of Optimality Theory, since, as we will show, this function is superfluous (despite its place in the popular conception of the structure of the theory). Rather, the essence of the two frameworks lies in one strategy or the other - generation or evaluation – so it is the very devices of generation and evaluation that a systematic formal comparison must compare.

This chapter's orientation is decidedly formal, since introductions to the theories have already been made. A formal approach is by nature highly powerful, forcing very basic properties to be stated explicitly. Often, our formulations may specify things which those who work with

the theories know intuitively. In other instances, they may clarify the systems in ways which challenge popular views.

## 2.1 Generation in the Derivational Framework

The derivational analyst formulates a system in which a surface form is determined from the underlying form by a series of rule applications, each providing some mutation or augmentation of structure. This is the generation strategy. In this section we review the constructs of the derivational framework which derive the underlying-surface relation: derivational sequences, rules, and rule ordering.

### 2.1.1 Derivational Sequences

From a series of mutations or augmentations of structure by rules, a sequence of representations builds up - a linguistic derivation, then, is a **sequence**. The derivations of all the surface forms of an entire language form a class, and a generative grammar of the language defines this class. This can be given the following simple algebraic outline (adapted from Soames 1974:124 and Chomsky 1971:183-4)<sup>10</sup>:

- (1) The class  $K$  of derivations in a grammar  $G$  is the class of finite sequences of representations  $P_1, \dots, P_n$  such that:
- (i)  $P_1$  is an underlying representation,
  - (ii) Each pair  $\langle P_i, P_{i+1} \rangle$  meets well-formedness requirements placed by  $G$ .

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<sup>10</sup>The reference to work of such antiquity is a consequence of the peculiar history of generative grammar, since study of the nature of rule application had its heyday in the 1960s and 1970s. Soames (1974) specifically addresses the formalisation of derivational systems.

Since our concern is with how the relation between underliers and surface forms is mediated, we do not now pursue any further the question of *how they are set up* by the analyst, nor how they are to be *interpreted* in cognitive terms or otherwise. Since our inevitably limited focus excludes these from inquiry, we merely assume a set, call it 'Un', whose members are precisely the underlying representations, and a set 'Su' whose members are the surface representations. To say that a form is an underlying form is to say that it belongs to 'Un', to say it is a surface form is to say that it belongs to 'Su'. The function specified by a grammar of the derivational framework is a serial composition of elementary functions, the rules, combined into a derivational sequence starting from the underlying form. The final member of that derivation is the corresponding surface form predicted by the grammar.

(2) Let the underlying-surface relation contain pairs

$un_a$  :  $su_a$

$un_b$  :  $su_b$

$un_c$  :  $su_c$

$un_d$  :  $su_d$

...

Let  $P_1, \dots, P_n$  be a derivation in K.

If  $un_x = P_1$  for  $x \in \{a, b, c, d, \dots\}$ , then  $P_n = su_x$ .

*The last member of a derivation is the surface counterpart of the underlying form at the start of the derivation.*

What (1) does is to characterise the working of the grammar while (2) reveals its result, the determination of the surface from the underlier. The clear distinction of the working of the grammar from its output specifically characterises the classical generativist position: that the

derivational grammar is blind to the surface it happens to traverse towards, and thereby offers an explanation of the facts at the surface.

We now turn our attention to rules, expressing the special relations between the successive structures of the derivation.

### 2.1.2 What Is A Rule?

Within a derivation  $P_1, P_2, P_3, \dots, P_n$ , each successive ordered pair of representations  $\langle P_1, P_2 \rangle$ ,  $\langle P_2, P_3 \rangle$ ,  $\langle P_3, P_4 \rangle$ , etc. – that is, each successive **step** of the derivation – constitutes the application of some rule. Thus, for the Sarcee forms in (3),

- (3) a.  $d\acute{in}\acute{i}$  'it makes a sound'  
 b.  $d\acute{in}\acute{i}t\text{'-}i$  with relative suffix

the underlying form is /  $d\acute{in}\acute{i}t\text{'}$  /, as revealed by forms with vowel-initial suffix (3b) and corroborated by the fact that the speaker still *feels a 't'* at the end of the word (3a) even though it is objectively absent from speech (Sapir 1933). Then, the derivation of (3a) contains the ordered pair,  $\langle d\acute{in}\acute{i}t\text{'}, d\acute{in}\acute{i} \rangle$ . Here, a rule of word-final consonant deletion has applied. A rule **R** is said to **apply** in a derivation  $P_1, \dots, P_n$  if there exists some  $i$  such that  $\langle P_i, P_{i+1} \rangle$  is a member of **R**. Thus, a rule defines a set of ordered pairs that can appear in the derivations of a language. A set of ordered pairs is a relation (Partee, ter Meulen and Wall 1990:29), so a rule is a **relation**.

As a relation, a rule has a **domain** - the set of structures from which the rule maps, and a **range** - the set of structures to which it maps. A rule of final consonant deletion has the domain 'structures with final consonants' and the range 'structures with no final consonants'. The rule only adds a new structure to the derivational sequence when the previous structure falls within its

domain.<sup>11</sup> The domain and range, however, are not usually sufficient to define a relation,<sup>12</sup> and this is true of phonological rules. The range of final consonant deletion is 'structures with no final consonants', but this allows all sorts of possible outputs from / ðiníʔ /, as in (4):

- (4) a. / ðiní /                      d. / ði/  
       b. / ðiníʔa /                e. / pélí /  
       c. / ðiníʔi /                f. / víná /

Any form ending in a vowel falls within the range of the rule-relation, not just the desired form / ðiní / (4a). In order to properly characterise a phonological rule, then alongside the specification of the domain, or **structural description** to which the rule applies, we replace the range condition with a specification of the **structural change** by which the second structure differs from the first. Thus word-final consonant deletion is formulated as follows:

- (5) a.  $C \rightarrow \emptyset / \_ \#$   
       b. Structural Description:  $C_i \#$   
       c. Structural Change:  $C_i \rightarrow \emptyset$

The output of the rule must differ from the input by the absence of the particular final consonant that is identified by the structural description. We represent this by co-indexing the consonant

<sup>11</sup>A qualification needs to be made for rules which insert structure, whether a feature or an association relation or syllable structure. These rules have an 'implicational' format (Roca 1994:46), e.g., [+nasal]→[-continuant] rather than a 'transformational' format [+continuant]→[-continuant]. When a structure meets the domain condition of an implicational rule [+nasal]→[-continuant], the material to be inserted may already be present ([+nasal,-continuant]). In that case, the rule is said to apply **vacuously**, which would generate an identity mapping.

<sup>12</sup>To see this, consider a relation between the letters of the English alphabet (the domain) and the numbers 1 to 26 (the range). Now, what is 'a' mapped to? If we wish to adopt the conventional order and identify 'a' with '1', for example, we must additionally specify this convention, stating which letters are related to which numbers.

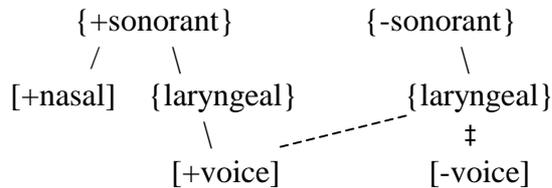
mentioned in the structural description (5b) with the consonant given in the structural change (5c): they are crucially one and the same. Such a definition now rules out augmenting the segmental string with a vowel in application of the rule as in (4b,c); rather, the rule states that the *t'* must be taken out. However, we also require that while the final consonant is deleted, *other* parts of the structure are not permitted to change at random, leading to forms like (4d) or (4e) or (4f). Pieces of structure must either exhibit the structural change (s.c.) of a rule, or else identity (id.), as in (6). This halts the absurdity of random variation.

(6)	d	ì	n	í	t'
	d	ì	n	í	∅
	id.	id.	id.	id.	s.c.

It remains possible for several structural changes to apply at once, by permitting two, or more, rule applications simultaneously within a single derivational step (and all other elements remaining identical). One question is what happens when the structural description of a single rule is met several times in a word. This can happen with rules applying to word-medial positions, such as consonant assimilations in words with several clusters, or vowel lengthening in words with multiple syllables. Chomsky and Halle (1968:344) considered that structural changes took place at all places where the structural description is met in a single step, but Johnson (1972) argued that it was necessary to separate them, applying structural changes singly at successive steps in the derivational sequence for positions from left to right or right to left in the word. The application of two *distinct* rules at the same step has also been countenanced in some proposals (Koutsoudas, Sanders and Noll 1974, Hyman 1993). In autosegmental phonology, it has remained ambiguous whether the spreading and delinking of features depicted within a single diagram apply one after the other or simultaneously (Kenstowicz 1994:103). We give the

example of voicing assimilation of obstruents to nasals, where [+voice] spreads from the nasal to the obstruent and any [-voice] value of the obstruent delinks and deletes.

(7) *Spreading and delinking: together, or in some sequence?*



If the theory allows only one structural change at each step, then each structure in the sequence is uniquely determined by the rule applying at that step, and since uniquely determined output is the defining characteristic of a function (Partee, ter Meulen and Wall 1990:30), rules are **functions**. Otherwise, rules are a less stringent kind of relation, each failing to uniquely determine its outcome, and the theory requires an additional formal operation which takes all the rules that apply at one step and produces from them a single ordered pair containing all the structural changes.

### 2.1.3 Rule Ordering and Regular Sequencing Constraints

The next issue is the sequence in which rules apply. If one rule  $R_a$  always applies before another rule  $R_b$  in some language, because the mapping by  $R_a$  from one structure to the next occurs at an earlier point in the sequence than the mapping by  $R_b$  from one structure to the next, then the following statement holds over the class of well-formed derivations:

(8) For all derivations  $P_1, P_2, P_3, \dots, P_n : \forall i \forall j [ (\langle P_i, P_{i+1} \rangle \in R_a \ \& \ \langle P_j, P_{j+1} \rangle \in R_b) \rightarrow i < j]$

*Whenever the two rules  $R_a$  and  $R_b$  both apply in a derivation,  $R_a$  always applies before  $R_b$ .*

This captures the regular sequencing of two rules.<sup>13</sup> The regular sequencing of  $R_b$  with a third rule  $R_c$  would be captured by a similar well-formedness constraint:

(9) For all derivations  $P_1, P_2, P_3, \dots, P_n : \forall i \forall j [ ( \langle P_i, P_{i+1} \rangle \in R_b \ \& \ \langle P_j, P_{j+1} \rangle \in R_c ) \rightarrow i < j ]$

*Whenever the two rules  $R_b$  and  $R_c$  both apply in a derivation,  $R_b$  always applies before  $R_c$ .*

Now, taking (8) and (9), it is not immediately possible to deduce (10), which regularises the sequential application of  $R_a$  before  $R_c$ .

(10) For all derivations  $P_1, P_2, P_3, \dots, P_n : \forall i \forall j [ ( \langle P_i, P_{i+1} \rangle \in R_a \ \& \ \langle P_j, P_{j+1} \rangle \in R_c ) \rightarrow i < j ]$

*Whenever the two rules  $R_a$  and  $R_c$  both apply in a derivation,  $R_a$  always applies before  $R_c$ .*

The argument is as follows. In a derivation where all three rules apply, they must of course apply in the sequence  $R_a$  before  $R_b$  before  $R_c$ . But in a derivation where only  $R_a$  and  $R_c$  apply, but not  $R_b$ , neither (8) nor (9) says anything about the sequence in which they come (they are both vacuously true, by falsity of antecedent). So there is no reason why  $R_c$  may not apply before  $R_a$ , contrary to (10).

So regular sequencing constraints are not themselves **transitive**:  $R_a$  always precedes  $R_b$  and  $R_b$  always precedes  $R_c$  does not imply  $R_a$  always precedes  $R_c$ , though they are **irreflexive** (rules do not apply before themselves) and **asymmetric** (if  $R_a$  always applies before  $R_b$ , then  $R_b$  does not apply before  $R_a$ ). Instead, (10) is achieved in a stronger theory in which rules are

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<sup>13</sup>I have avoided the expression "order of application" and instead adopted the expression "regular sequencing". This anticipates chapter five in which it is observed that derivational sequences are not necessarily orderable.

**ordered**, as in (11), because ordering relations are by definition irreflexive, asymmetric *and* transitive.

(11) Let  $<$  be an ordering on rules.<sup>14</sup>

If  $S < T$ , then for all derivations  $P_1, P_2, P_3, \dots, P_n$ ,

$\forall i \forall j [ ( \langle P_i, P_{i+1} \rangle \in S \ \& \ \langle P_j, P_{j+1} \rangle \in T ) \rightarrow i < j ]$

*Rules are ordered in a list, and each pair of rules always applies in the sequence given by their order.*

Now in the rule ordering theory we have that if  $R_a < R_b$ , and  $R_b < R_c$  then by transitivity  $R_a < R_c$ .

Then, by (11), all three regular sequencing constraints (8), (9) and (10) *will* be imposed.<sup>15</sup>

In the only comparable study of the formal properties of derivations, Soames (1974) notes that transitivity is required, but overestimates the response that is needed. In his terminology, an ordering relation is not necessarily transitive; only a *linear* ordering is transitive. Thus, he presents a theory like (11): “if T1 and T2 are transformations, then the statement that T1 is ordered before T2 imposes the following constraint:  $\forall i \forall j [ ( \langle P_i, P_{i+1} \rangle \in T1 \ \& \ \langle P_j, P_{j+1} \rangle \in T2 ) \rightarrow i < j ]$ ” (Soames 1974:130), but rejects it because “this characterisation does not require that the ordering [sic] relation holding between transformations be transitive” and “if it is the case that whenever grammars impose orderings, the orderings imposed are linear [and hence, transitive - RN], then we want a theory that is not just compatible with this result, but which predicts it.” (Soames 1974:131). Setting things straight, we do not want a theory which predicts linear order:

linear order IS the theory. As Pullum (1979:25) points out, Soames need only add a statement of

<sup>14</sup>The notation  $S < T$  is standard in mathematics for “S precedes T”, even though the opposite symbol “ $>$ ” is more familiar in linguistics from historical derivations, e.g. *\*vin > vino* “*vin* is the antecedent of *vino*”.

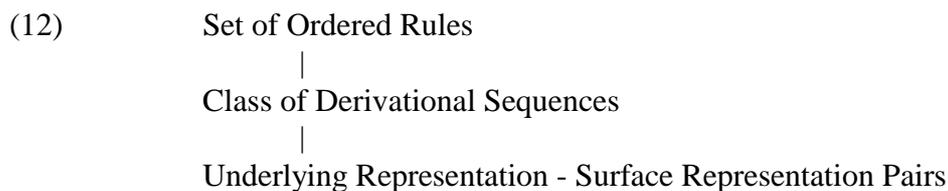
<sup>15</sup>(11) would need to be modified for theories of cyclic rule application, since the rules apply in sequence within one cycle, but the rules may apply again on the next cycle.

transitivity. Instead, Soames (1974:132) resorts to the more elaborate response of assigning numerical indices to transformations, ensuring linear order because the indices are “drawn from a linearly ordered system”. The natural numbers, to be sure, are linearly ordered, and provide a perspicuous notation (which I capitalise on), but they import a whole raft of other properties that have interested mathematicians for centuries but which have no use in derivational systems: for example, numbers are unbounded, so their incorporation implies that a grammar may contain an infinite number of rules, R1,R2,R3,R4,... , and that grammars with a finite set of rules (i.e. all real grammars) intrinsically stop short of the full capacity available. All we actually want is linear order.

In this section, we have recognised that rule-based grammars depend on an ordering relation, which is used to impose natural restrictions on the regular sequencing of rules in derivations. The overall structure of the framework is summarised in the next section.

#### 2.1.4 Summary: Rule-Based Grammar

The three interrelated levels in (12) represent the derivational framework:



The 'bottom' level has the list of underlying forms paired with the surface forms which realise them. These forms are the first and last members of the derivations, which themselves reside, as a class (as in 2.1.1), on the middle level. In the derivations, the determination of surface forms from underlying forms is decomposed into a series of ordered pairs whereby each successive form is mapped from its predecessor. What counts as a well-formed derivational sequence is

determined from the rules and their ordering at the top level. Each ordered pair in the derivational sequence must constitute the application of some rule (as in 2.1.2) and the ordering of rules imposes constraints of regular sequencing on the application of rules (as in 2.1.3).<sup>16</sup> In table (13) below, we recall these formulations.

(13)

<b>Rule System</b>	<b>Effect of Rule System on Derivations</b>
A set of rules.	In a derivation $P_1, \dots, P_n$ in $K$ , each pair of successive representations constitutes the application of some rule, i.e. $\langle P_i, P_{i+1} \rangle \in R$ for some rule $R$ .
A (partial or total) ordering on rules: that is, a relation $<$ between rules that complies with axioms of irreflexivity, asymmetry, transitivity.	Rule ordering statements $S < T$ impose constraints on derivations $P_1, \dots, P_n$ of the form $\forall i \forall j [ (\langle P_i, P_{i+1} \rangle \in S \ \& \ \langle P_j, P_{j+1} \rangle \in T) \rightarrow i < j ]$ .

Bromberger and Halle (1989) also cite other conventions used in the construction of derivations in phonology: the affiliation of rules to different strata, cyclic application of some rules over successively more inclusive morphological domains. These are substantial issues in their own right, and purely for simplicity's sake we delimit our formal enquiry to a single stratum of rules which all apply to the same morphosyntactic domain. This allows us to focus on comparing the essential formal system of rules and derivations with the optimality-theoretic alternative.

<sup>16</sup>The well-formedness of derivations also depends on the requirement that obligatory rules apply whenever a member of the sequence falls within their domain unless ruled out by the regular sequencing constraints and/or possibly other derivational constraints.

## 2.2 Evaluation in the Derivational Framework

Some work in generative phonology has proposed that the well-formedness of the steps in derivational sequences (see (1)) is decided not only by the basic system of ordered rules, but in part by constraints against which the structures produced by rules are measured. Here, we discuss the formalisation of constraining derivations this way, and show that the full complexity of this approach is greater than has been acknowledged, departing from the basic generation system.

### 2.2.1 Blocking Constraints

One example is from Modern Hebrew (McCarthy 1986). A rule of schwa deletion which fails to apply just in case the immediately adjacent consonants are identical. Form (14a) illustrates the deletion, which does not obtain in (14b) when the schwa is flanked by two identical consonants.

- (14) a. \*kaʃəru, kaʃru                    'they tied'  
       b. titpaləli , \*titpalli    'I will pray'

We would want a rule somewhat like (15a), whose structural description contains the condition that the flanking consonants must differ in some feature or other.

- (15) a.  $\text{ə} \rightarrow \emptyset / \text{VC}_1 \_ \text{C}_2 \text{V} \text{ (C}_1 \neq \text{C}_2\text{)}$   
       b.  $\text{ə} \rightarrow \emptyset / \text{VC} \_ \text{CV}$   
       c. \* $\text{C}_1 \text{C}_2$  where  $\text{C}_1 = \text{C}_2$

An alternative is to omit the condition that the neighbouring consonants differ, as in (15b), but concomitantly posit a constraint (15c) that prohibits identical adjacent consonants, which will *block* the application of (15b) where necessary. This constraint is the Obligatory Contour Principle (OCP). One can think of offending structures as being ruled out by the evaluation of a tentative rule application, accepted into the derivation depending strictly on satisfaction by the constraint (denoted in (16) by a tick  $\checkmark$  or cross X).

(16)

kaʃəru		titpaləli	
?↓		?↓	
	OCP		OCP
kaʃru	$\checkmark$	titpalli	X

A simple way of formalising constraints of this kind might be as in (17a): a constraint C defines a set of structures and no structure outside this set is allowed in a derivation. This would even require that underlying forms, as the first members of derivational sequences, must satisfy C. However, it has been proposed that derivational constraints are more selective, blocking only some rules (Kisseberth 1970a, Archangeli and Pulleyblank 1994, Idsardi 1997). The affected rule(s) may be named in the requirement on derivations as in (17b).

(17) Let  $P_1, \dots, P_n$  be any derivation in K. Let  $i, j$  range over the subscripts 1 to  $n$ .

a.  $\forall i [P_i \in C]$

*All structures in the derivation must satisfy constraint C.*

- b.  $\forall i[\langle P_i, P_{i+1} \rangle \in R \rightarrow P_{i+1} \in C]$

*A derivation may contain an application of the rule R provided the resulting structure satisfies constraint C.*

- c. Applied to Modern Hebrew: a derivation may contain the rule of interconsonantal schwa deletion provided the outcome has no adjacent identical consonants.

In a similar example with a new twist, a vowel deletion rule in the Amerindian language Tonkawa applies in the environment VC\_\_CV. This means that it fails just in case it would create clusters of three consonants. Kenstowicz (1994:527) offers two versions of the derivational constraint affecting this rule:

- (18) a.  $V \rightarrow \emptyset / X\_Y$

Condition: block if result violates constraint \*CCC

- b.  $V \rightarrow \emptyset / \sigma\_ \sigma$

Condition: block if result is not exhaustively syllabifiable

Version (18b) is intended to go beyond the segmental string and take account of contemporary syllable theory. Thus, the bias against clusters of three consonants is to be explained in turn by two constraints: (i) a general constraint against two consonants in either syllable onset or syllable coda - single onset and coda consonants lead to maximum clusters of two consonants word-medially: .CVC.CVC.; (ii) a requirement that all segments be licensed by (or have a legitimate place in) syllable structure - so no consonants between syllables, \*.CVC.<C>.CVC. .

The complexity of this evaluation has not been made formally explicit, however. It cannot be done merely by testing the output of the rule. For, if we block the rule whenever it leaves an

unsyllabified consonant, we would block every time - correctly (19, left) and incorrectly, indicated by  $\bullet^*$  (19, right):

(19)

CVC.CV.CV	
?↓ Deletion	
Licensing	
CVC.<C>.CV	X

CV.CV.CV	
?↓ Deletion	
Licensing	
CV.<C>.CV	$\bullet^*$ X

In fact, the rule is blocked if it would create a string which is not merely *unsyllabified*, but *unsyllabifiable*, a stronger condition that must be evaluated by taking into account further syllabification rules also, as in (20). Since the onset of the following syllable and the coda of the preceding syllable are both occupied, leaving no way to syllabify the consonant, *then* the original deletion rule is blocked:

(20)

VC.CV.CV	
?↓ Deletion	
Licensing	
VC.<C>.CV	
?↓ Onset Syllabification	
<i>does not apply</i> (*VC.CCV)	
?↓ Coda Syllabification	
<i>does not apply</i> (*VCC.CV)	X

In contrast, CV.CV.CV will be reduced to CV.<C>.CV then CVC.CV by coda syllabification, and since the consonant is eventually licensed, no overzealous blocking will result.

Thus, while Kenstowicz's (1994:527) condition of unsyllabifiability is both accurate and true to contemporary syllable structure theory, a new degree - even dimension - of complexity has been added to the derivational system. We started out with the notion that rule application could be restricted by derivational constraints that prevent some outputs, keeping a sense of integrity to the particular derivational step as originally set out in (1ii) above and reiterated by Chomsky (1998) as an imperative of Minimalist theory. Now we have a scenario in (20) of evaluating not the outcome of the rule itself, but the outcome following a number of rules - this rule and the rules of syllabification. A new requirement on derivations, significantly more complex than the earlier formalisation of derivational constraints in (17b), is involved.<sup>17</sup> Yet this approach, underformalised and more complex than hitherto acknowledged, is not strictly essential. In principle, all restrictions on the application of rules can be put in the structural description which specifies the domain of the rule mapping. Indeed, Calabrese (1995) proposes that blocking reduces to precisely this, and applies it at least for a simple case. In the Tonkawa rule here, the rule needs to contain the condition that the syllable containing the vowel to be deleted (V) and the preceding syllable are both open syllables: ...CV.CV.CV... This condition is apt in its reference to syllable structure, without resorting to a complex evaluating mechanism.

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<sup>17</sup>In order to maintain evaluation at the original step, it might be said to arise in a different way: all consequences of constraints are also constraints, so \*CCC is a constraint because it follows from exhaustive syllabification and a ban on two consonants in onsets or codas. However, for structures where syllabification principles are in force, lack of CCC is simply an epiphenomenon, but \*CCC as a constraint in its own right affects structures that syllabification principles do not (structures at derivational stages prior to their syllabification). By this very strength, \*CCC is more than a logical consequence, it is an extension. Hence, the proposed grammar contains an enriched, self-extending system of derivational constraints, a development in complexity alternative to the evaluation in the text.

### 2.2.2 Constraints Triggering Repairs

In addition to the blocking facility, another function has been attributed to constraint statements - that of *triggering* repair-operations whose output satisfies the constraint violated by the input. For example, concatenations of morphemes can bring together material which violates a constraint statement. However, this appeal to constraints is essentially a re-conceptualisation of the structural description of a rule.

Yawelmani Yokuts employs the rule in (21) (Kisseberth 1970a):

$$(21) \quad \emptyset \rightarrow V / C\_CC$$

Given this rule, one can identify the notions of constraint and repair strategy. One might say that the presence of CCC (or perhaps unsyllabifiable <C>) in some structure in a derivation is evaluated negatively and is subject to an operation to repair it. The structural change of the rule is the insertion of a V between first and second of the three consonants, a site denoted in (22) by  ${}_1\emptyset_2$ . Or, one might say, the vowel insertion is the repair operation to avert a \*CCC violation.

$$(22) \quad \begin{array}{lll} \text{Structural Description:} & C_1C_2C_3 & (\text{"Constraint: *CCC"}) \\ \text{Structural Change:} & {}_1\emptyset_2 \rightarrow V & (\text{"Repair: } \emptyset \rightarrow V \text{"}) \end{array}$$

Note, however, in (22) that the insertion of V cannot occur just anywhere in the word, it must be stated *where* in the configuration CCC it is employed - between the first and second consonants.

The structural change of a rule crucially depends on the structural description for its intelligibility. Because of this, any additional independent constraint statement \*CCC in the language is redundant. Myers (1991) makes the same argument with examples of rules of English. Constraints-as-triggers must be *none other than the structural descriptions* of rules, and

repairs none other than structural changes, which are meaningless without being indexed to a structural description.

We briefly consider a couple of rejoinders to this. First, a putative advantage of appealing to constraints is that both effects of a constraint - triggering repairs and blocking other rules - may occur in a language. For example, Yawelmani Yokuts both repairs and blocks CCC sequences. Or the same constraint may block in one language and trigger repairs in another, such as the OCP (Yip 1988, Myers 1997a).<sup>18</sup> But in a derivational theory based on rules we must re-interpret the informal notion that constraints may both repair and block by saying that one configuration of phonological structure may be present both as the structural description of a rule and as a derivational constraint on other rules.

Second, Goldsmith (1990:318ff, 1993) attempts to generalise the blocking-and-triggering approach with the proposal that phonological rules apply if, and only if, their effect is to increase 'harmony' (i.e. increase satisfaction of constraints). In Yokuts, one might attempt to reduce the epenthesis rule (21) to a constraint \*CCC (or \*<C>) and the simple rule  $\emptyset \rightarrow V$ , which can break up clusters in order to increase harmony with respect to \*CCC. However, we still need to determine where the vowel goes: it could either go at C\_CC or CC\_C. If rules apply if and only if they would increase harmony, then we require the presence of a further constraint which deems that CV.CVC.C... is an improvement in harmony, but CVC.CV.C... is not. The problem is that both syllable patterns exist in the language: *su.doḱ.hun* 'removes'; *wag.ci.wis* 'act of dividing'. There being no constraint against either pattern in the language, harmony fails to distinguish between the two possible epenthesis sites. We must still index vowel insertion to the right position in the structure, which is what the rule (22) achieves.

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<sup>18</sup>The supposed dual effect of constraints in blocking and repair is also a problematic ambiguity, as observed by Prince and Smolensky (1993:207) and Bird (1995:12-14): will a given constraint block the output of a rule, or will it admit the rule's application but then trigger a repair of its output? Apparently this must be resolved on a case-by-case basis. This has led researchers either to abandon blocking-constraints (Myers 1991, Calabrese 1995), or to abandon rules (Scobbie 1991, Prince and Smolensky 1993).

In conclusion, constraints are an additional facility imposed on the essential system of generation by rules. Although the appeal to constraints is empirically motivated, we have found that the supposed blocking and triggering effects are underformalised, and that the technical difficulties encountered are overcome by reverting to rules.<sup>19</sup> This does not motivate a meaningful formal comparison between these constraints and the constraints in the optimality framework. Rather, rules and their effects must be compared with the optimality framework's constraints and their effects.

Having reviewed the appropriate specification of the derivational framework in 2.1 and 2.2, we move on to the optimality framework.

### **2.3 Generation in the Optimality Framework**

Just as the use of constraints is a formally non-essential extension to the basic generation system of the derivational framework, we make the complementary but innovative claim that generation is eliminable from the evaluation system of the optimality framework.<sup>20</sup> Surface phonological representations are optimal among *all possible* representations defined by the theory of phonological representation, not some set of forms generated by mutations to the underlying representation.

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<sup>19</sup>Constraint thinking can also be seen as antithetical to the explanatory intentions of the generation system set out in 2.1.1. For if the constraints which act on derivations are motivated by phonotactic patterns of the language (Sommerstein 1974, Singh 1987, Goldsmith 1993), then the derivation does not explain the surface facts but is itself driven by them (Scobbie 1991).

<sup>20</sup>This proposal was given to the 1997 Spring meeting of the Linguistic Association of Great Britain, and appears in Norton (1998). I am grateful to the LAGB audience and the editor of the volume for their comments.

### 2.3.1 Is Optimality Theory Derivational?

The structure of optimality-theoretic grammar given in the seminal texts (Prince and Smolensky 1993, McCarthy and Prince 1993a,1993b,1994) and maintained since (Kager 1999, McCarthy 2002) goes as in (23), where from each underlying form we generate a set of structures as candidates for the realisation of the form. This function is labelled 'GEN', short for 'generator'. This is followed up by an evaluation function 'EVAL' which assesses the relative adherence of candidates to a hierarchy of constraints, whereby one candidate is delivered up as optimal.<sup>21</sup>

$$(23) \quad \text{GEN (in)} \rightarrow \{ \text{out}_1, \text{out}_2, \dots \}$$

$$\text{EVAL} (\{ \text{out}_1, \text{out}_2, \dots \}) \rightarrow \{ \text{out}_k \}$$

This gives us a theory which *derives* an output from an input. The derivational perspective is suggestive of a computation of Gen and Eval (Ellison 1994), and suggests the possibility of extending the structure of the theory by re-applying the Gen-Eval combination in successive steps, either open-endedly (Prince and Smolensky 1993:4-5, McCarthy 2000), or a minimal number of times (Rubach 2000). In rule-based derivations, structures are generated one from the other in series, (24a). Prince and Smolensky (1993) developed the alternative in (24b) whereby several structures are generated together.

(24) a. Serial Generation	b. Multiple Generation	c. No Generation
/•/ → • → • → •	/•/ → • • •	??? • • •

<sup>21</sup>The seminal texts say that Eval "comparatively evaluates", "rates", "imposes an order on" the forms input to it, though their schematic representation, repeated here, shows a filter which outputs a single form rather than an ordering of forms.

The following sections argue that Optimality Theory has reached, without acknowledgement, a stage where generation of structure from structure plays no part at all (24c), and the grammar is purely an evaluative filter. While this requires abandonment of the popular conception of the theory, the result is a more explanatory system.

### 2.3.2 *How Are Candidates Admitted?*

To give concrete motivation to the discussion, a tableau is selected from the literature (Myers 1997a, 1997b) concerning some tone alternations in Shona. The brief data in (25) show that the high tone realised on the vowels of the word for 'knife' is lost when the word follows the copula proclitic, an [i]-vowel itself with a high tone.

- (25) a. b́angá      'knife'  
       b.  í banga    'it is a knife'

For the tableau analysis in (26), the concatenated input form comes with both high tones associated to their vowels. The constraints used are defined in (27). However, as candidate (26a), this form violates the OCP which prohibits adjacent identical elements. Candidate (b), for which the second high tone is absent, satisfies the OCP. It turns out that candidate (b) is better than a number of other candidates (c,d&e), and is passed as optimal. This predicts the surface form (25b) given above.

(26)

Input: H H   / \ i banga	OCP	PARSE(T)	LEFT-ANCH	MAX-IO(T)	MAX-IO(A)
a. H H   / \ i banga		*!			
b. H   i banga				*	**
c. H H   / \ i banga			*!		*
d. H H     i banga				*!	*
e. H / \ i banga				*!	*

(27) OCP Identical tones on adjacent tone-bearing units are prohibited.

PARSE(T) A tone must be associated with a tone bearer.

LEFT-ANCH If an output syllable  $\alpha$  bears a tone, then  $\alpha$  is the leftmost syllable in a tone span if and only if its input correspondent is the leftmost syllable in a tone span.

MAX-IO(T) Every tone in the input has a correspondent in the output.

MAX-IO(A) Every association relation in the input has a correspondent in the output.

Ranking: OCP, PARSE(T), LEFT-ANCH >> MAX-IO(T) >> MAX-IO(A)



and is merely in the background, then the statement that candidates are 'provided by Gen' lacks serious theoretical content.

### 2.3.3 *The Theoretical Role of Gen*

Gen is described by its creators as a function, with the qualities explained in (29). Let us then examine its nature as a function.

(29)

a. "Gen consists of very broad principles of linguistic form, essentially limited to those that define the representational primitives and their most basic modes of combination." (McCarthy and Prince 1994:337)

b. "Gen contains information about the representational primitives and their universally irrevocable relations." (Prince and Smolensky 1993:4)

c. "Gen... generates for any given input a large space of candidate analyses by freely exercising the basic structural resources of the representational theory." (Prince and Smolensky 1993:5)

From (29a&b) particularly, it appears that principles of linguistic structure are intrinsic to what Gen is. Thus, Gen produces phonological structures, but in doing so might be understood as actually defining phonological structure, *generatively*, starting from some initial structures. If one asks the question of what constitutes a phonological structure, the answer will be:

- Any structure generatable from an input structure by Gen, and any input structure itself, is a phonological structure.

This faces the problem that, although the structure known as the Eiffel Tower cannot be generated from a phonologically plausible input, there seems nothing to stop the postulation of

the Eiffel Tower, or (28b), as an input, and hence, by definition, as a phonological structure. And if we have (28b) as an input, we will have variations of this monster delivered by Gen as candidate outputs. However, there is another answer to what constitutes a phonological structure which is more principled, not dependent on some contingent input structures. This is an *axiomatic* definition:

- Any object consisting of phonological primitives (features, prosodic units) related to each other by some basic principles of permissible combination is a phonological structure.

This excludes the Eiffel Tower, and, with a little more work, (28b), but would be expected to admit all the input and output forms on tableau (26), and so on.<sup>22</sup>

To confirm the primacy of the latter definition, we refer to the basic mathematical theory of functions (Partee, ter Meulen and Wall 1990:30ff). A function is a set of ordered  $\langle a, b \rangle$  whose left and right members are taken from two sets A and B, such that the right members are uniquely determined from the left members. Prince and Smolensky (1993:4) tell us that "each input is associated with a candidate set of possible analyses by the function Gen". So for Gen, the left members are the input structures and the right members are the candidate sets, and each input is uniquely associated with one particular collection of candidates. But these entities – inputs, candidate sets – rest on there being a pre-defined set of phonological structures. The situation is as in (30). First, the representational theory specifies what phonological structures may contain, which defines the set of possible phonological structures **P** (an explicit formulation is in Bird 1995). Gen is a function from structures (members of **P**) to sets of structures (members of the set of subsets of **P**, or **power set** of **P**). In each language a finite subset of these structures are the

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<sup>22</sup>Quote (29c) seems closer to this approach, for it recognises a "representational theory" whose resources Gen must supposedly draw on, and which must therefore be distinct from Gen.

underlying forms, the set  $U_n$ . The restriction of Gen to  $U_n$  gives us the candidate sets from which the grammatical forms of that language are selected.

(30) Some Entities in the Theory

$P$  the set of possible phonological structures

Gen a function from  $P$  to the power set of  $P$

e.g.  $p_k \rightarrow \{p_1, p_2, p_3, \dots\}$  where the  $p_i$  are phonological structures

$U_n$  a finite subset of  $P$  – *the set of underlying structures*

$Gen|_{U_n}$  the restriction of Gen to  $U_n$  – *which supplies a candidate set for each underlying form*

This brings out the theoretical claim that Gen embodies: the candidate set is a function of the underlying representation; each input determines which candidate outputs are in and which are out. One input form has one candidate set, another input form has another. We now show that this claim has effectively been abandoned.

The admission of candidates is guided by the principle of Inclusiveness:

(31) **Inclusiveness** (McCarthy and Prince 1994:336)

The constraint hierarchy evaluates a set of candidate analyses that are admitted by very general considerations of structural well-formedness.

The intention is that associated with an input is not just one possible derived form, but very many structures varying from the input in very general ways. McCarthy and Prince (1994,1995) build on the formative work of Prince and Smolensky (1993) by liberalising the generation of candidates. Epenthesis sites may be generated in Prince and Smolensky (1993), but McCarthy

and Prince (1994) also propose that the segment structures of epenthesis also be generated. They justify this using Makassarese, as reproduced in (32), where epenthesis in coda position is constrained by the Makassarese restriction that admits only glottals stops and velar nasals in codas. Epenthetic segment structures are evaluated against the Coda Condition of Makassarese if they are generated. This condition and other interacting constraints are stated in (33).

(32) Makassarese (McCarthy and Prince 1994:336)

/jamal/	CODA-COND	ALIGNR	FINAL-C	MSEG	NO-NAS
☞ jamal   aʔ		*		**	
jamal   aŋ		*		**	*!
jamal   at	*!	*		**	

- (33) CODA-COND            Codas may only contain ʔ or ŋ.
- ALIGNR                    Align the right edge of the stem with the right edge of a syllable.
- FINAL-C                    Words must end in a consonant.
- MSEG                        Segments must be morphologically sponsored.
- NO-NAS                     Segments must not be +nasal.

In the opposite case to epenthesis, phonetic absence is provided for in Prince and Smolensky (1993) by failure to parse input segments into syllable structure, but could be captured if input segmental structures are permitted to be absent from candidate outputs. This is advocated by McCarthy and Prince (1995:268), who point out that it avoids the problem of having to specify for an output constraint whether it refers to all elements or only the parsed

elements, since they note that both kinds have been tried in the literature. For example, will the OCP prohibit any adjacent, identical elements in a language or only adjacent identical, parsed elements?<sup>23</sup>

Thus we have that candidates may have feature structure that is not present in the input, and they may lack features that are in the input. If these considerations are fully general, as the Inclusiveness principle suggests, then the logical result is that candidate structure varies from the input structure without limit, and Gen admits any, and hence every, possible phonological structure as a candidate, every time (34). This is Inclusiveness at its logical extreme. Whereas a rule generates a new form that differs from its predecessor in a specific and interesting way, Gen generates forms that differ from its input in literally *no* particular or crucial way.

(34) Gen:  $\langle \text{in}_a, \mathbf{P} \rangle, \langle \text{in}_b, \mathbf{P} \rangle, \langle \text{in}_c, \mathbf{P} \rangle, \dots$

*Gen maps every input back to the whole set P.*

Gen is now a problematic item to retain in a theory, for it is now *unrestrictive*: nothing is ever crucially excluded. Moreover, Gen is *uninformative*: a different input never has a different candidate set; every input is always mapped to the same thing, ad nauseam. And Gen is *redundant*: what it produces (ad nauseam) is a set that is already known and independently specified. One can simply state – for all cases – that the possible candidate outputs are the members of P: this doesn't need to be re-derived over and over from every input.

Summarising this section, we have that: (i) Gen is a function; (ii) Gen does not define phonological structure, but instead maps structures to structures and thus itself requires an independent definition of phonological structure; (iii) Gen would be of substance as a function if

---

<sup>23</sup>As pointed out by Idsardi (1998), however, the parsed/unparsed element distinction and the constraint PARSE is still necessary in order to require prosodic structure at all.

its outputs differed in useful ways depending on its input, but they do not; (iv) the optimal form is in all cases one of *the* set of all possible phonological structures, not one of a set that depends on the particular input at hand.

#### 2.3.4 *Maintaining Accountability To The Input*

If we remove Gen from the general structure of optimality theory as in (35), however, it is not clear how the optimal output relates to the input. There must be some accountability to the input, without which all words would turn out the same (Chomsky 1995:224) – the one optimal member of  $\mathbf{P}$ .<sup>24</sup>

$$(35) \quad \text{EVAL}(\mathbf{P}) \rightarrow \{\text{out}_k\}$$

Accountability to the input is provided by the Correspondence Theory of relations between input and output structures developed in McCarthy and Prince (1995). The need for a theory of correspondence to maintain the accountability necessarily follows from the derestriction of Gen, and by incorporating it into the discussion we can demonstrate more comprehensively how the argument against Gen goes through.

As soon as McCarthy and Prince (1994) propose the provision of epenthetic segment structure, it becomes necessary that a distinction be made between segments originating in the input and the potential epenthetic segments. These are discriminated by a constraint MSEG in (33) or in the reformulation by McCarthy and Prince (1995), DEP, defined in (37) below.

Augmenting the earlier tableau for Makassarese epenthesis, (36) shows that the candidate

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<sup>24</sup> Heck *et al* (2002) argue that in syntax – unlike phonology – accountability to an input and deriving the candidate set from an input are *both* unnecessary.

structure *jamalal* may be arrived at by considering the stem *jamal* to be augmented in two possible ways, with different consequences against the additional constraint of CONTIGUITY.

(36) (Augmented version of (32))

/jamal/	CONTIGUITY	CODA-COND	ALIGNR	FINAL-C	DEP	NO-NAS
Ⓢjamal   aʔ			*		**	
jamal   aŋ			*		**	*!
jamal   at		*!	*		**	
jamal   al		*!	*		**	
jama la l	*!	*			**	

(37) DEP A segment in the output must have a correspondent in the input.

CONTIGUITY The portion of the output string standing in correspondence forms a contiguous string.

Thus, the relation between a potential output and the input is not necessarily absolute, and various alternative relationships may be subjected to evaluation against Faithfulness constraints like MAX, DEP, and CONTIGUITY (McCarthy and Prince 1995). Furthermore, however, we may claim that the system of correspondence relations will leave generation redundant by taking over the job of relating the output back to the input which was originally an auxiliary benefit of a restrictive Gen.

Consider how the correspondence relations are assigned. Take the string /blurk/. /blurk/, like any other string, is guaranteed to appear on every tableau, as illustrated in (38). The /blurk/ example is taken by McCarthy and Prince (1995:14) to “emphasise the richness of Gen”, but of

course that “richness” is a loss of theoretical content, because it means that Gen plays no role in selecting candidate sets.

(38)

<b>b l u r k</b>	
------------------	--

For the particular tableau associated with an input structure /blik/, say, the correspondence relations considered along with the candidate string /blurk/ are all and only those which relate the contents of /blurk/ to the contents of /blik/. The first six cases of /blurk/ in (39), where correspondence relations are illustrated by means of numerical co-indexing, are some of the many relations that will be evaluated for the input /blik/, but the correspondence relation given for the starred string, corresponding to, say, /b<sub>i</sub>a<sub>ii</sub>n<sub>iii</sub>/, will not be evaluated.

(39)

/b <sub>1</sub> l <sub>2</sub> i <sub>3</sub> k <sub>4</sub> /	
<b>b<sub>1</sub>l<sub>2</sub>u<sub>3</sub>r<sub>4</sub>k<sub>4</sub></b>	
<b>b<sub>1</sub>l<sub>2</sub>u<sub>3</sub>r<sub>4</sub>k</b>	
<b>b<sub>1</sub>l<sub>3</sub>urk<sub>4</sub></b>	
<b>b<sub>1</sub>l<sub>2</sub>urk</b>	
<b>b<sub>4</sub>l<sub>2</sub>u<sub>1</sub>r<sub>3</sub>k</b>	
<b>b l u r k</b>	
...	
<b>*b<sub>i</sub>l<sub>u<sub>ii</sub></sub>r<sub>iii</sub>k</b>	

This means that although the output structures themselves that appear on tableaux are not a function of the input structure, the assignment of correspondence *is* a function of the input structure. A correspondence relation must correspond to the input, so the input is the decisive factor in deciding what is and is not an acceptable correspondence relation, even though it is not a factor in deciding what is and is not an acceptable output structure.<sup>25</sup>

Finally, we must crucially note that the argument thus far has been confined, by starting assumption, only to phonological structure. Although the phonological structure of candidate outputs can vary without limit, the morphological structure of the input is often assumed not to vary for the candidate output structures. Thus it could be objected that a Gen function freely generates phonological structure while holding other linguistic structure invariant. However, Gen is not necessary here either: a simple alternative is to assume that morphological and syntactic structure is constant across input/output correspondence relations. Thus, in tableau (36), candidate *jama/la/l* has a morphological Stem *jama...l* because those segments correspond to an input sequence identified as a Stem. Or we could assume that morphological (and syntactic) structure can be assigned freely in candidate structures, and evaluated against constraints. After all, optimality theory is offered as a theory of overall grammar, not merely phonology. Either way, the argument against Gen is not contingent on the simplificatory confinement to phonological structure, and goes through: if correspondence relations are assigned between possible outputs and the input, there is no motivation left for actually generating the outputs from the input.

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<sup>25</sup> Of course, we could call the function that assigns correspondences between inputs and possible structures 'Gen' if we wish, as McCarthy and Prince (1995:263) do when they say "one can think of Gen as supplying correspondence relations between S1 [the first string of the correspondence, here the input - RN] and all possible structures over some alphabet", as suggested to them by others. But how is one to think about Gen? Gen is (or was) short for 'generator', and there is now no generation of structure from the underlying structure as there is in rule-based theory and as there is in the theory of Prince and Smolensky (1993), which came prior to the liberalisation which rendered generation vacuous.

### 2.3.5 Optimality Theory Without Gen

The origin of information on a tableau is now summed up in (40):

(40)

representational primitives and principles of combination

↓

set of possible structures  $P$

↓ ↓

Constraint set  $Con$

input  $in \in P$ , outputs  $out_i \in P$

Ranking  $\ll$

↓ ↓

↓

/ in /	$C_1$	$C_2$	$C_3$	...
{...⟨ in, out <sub>i</sub> , $R_j$ ⟩...}				

$R_j$  is some correspondence

relation between in and out<sub>i</sub>

The output structures that appear on the tableau are not derived from the input. Both come from the set of possible structures, which itself comes from the basic principles of what (phonological) structure looks like. The candidates themselves have a triple form, consisting of the input structure, a potential structure (from  $P$ ), and one of the logically possible correspondence relations between that output and the input. The presence of the input structure and the correspondence relation within the candidate is necessary for evaluating the preservation of

properties of the input in the output. For example, evaluating the preservation of linear order of elements requires reference to input order.

We have shown that, although it would not be viable merely to cancel the Gen function from the usual Gen-Eval scheme without losing all connection between the input and output, the use of correspondence relations between the input structure and the possible output structures enables an Eval function to stand without Gen:

$$(41) \quad \text{Eval} (\{ \langle \text{in}, \text{out}_i, \mathbf{R}_j \rangle \mid \forall \text{out}_i \in \mathbf{P}, \forall \mathbf{R}_j \subseteq \text{in} \times \text{out}_i \}) = \{ \langle \text{in}, \text{out}_k, \mathbf{R}_l \rangle \}$$

*For each input, evaluation of all possible ‘input,output,correspondence’ triple forms delivers some triple (or triples) as optimal.*

In this way, Optimality Theory may abandon the generation of structure from structure and shift the explanatory burden totally, not merely primarily, over to evaluation. This brings the theory closer to the actual practice of optimality-theoretic analysis, since, following the liberalisation of Gen by McCarthy and Prince (1995), crucial recourses to Gen are not made anyway. Everything is accounted for, in an alternative formal system – an evaluation system.<sup>26</sup> It now remains to specify more fully how a candidate is evaluated as optimal in the evaluation system.

---

<sup>26</sup> This is not achieved by Russell (1997) who, while recognising that candidate sets are not a function of inputs, assumes that they are "primitive" (Russell 1997:115). However, it is important that the infinite candidate sets are *not* merely received as unanalysable, unending lists, but are entirely generated from an apt finite definition of phonological representations (Bird 1995). The difference between generating candidates from an input and generating them from the axioms of phonological structure is akin to generating the set of all positive integers from the positive integer '1' under the operation of addition, and generating them by constructing the number system in set theory.

## 2.4 Evaluation in the Optimality Framework

With generation being shown non-essential to the optimality framework, we now flesh out the form of optimality-theoretic evaluation in this section. We then have a pure evaluation system which can be compared to the generation system of 2.1.

### 2.4.1 Optimality

In Optimality Theory, the surface form is selected from a number of potential candidates by an evaluation which places them in an order of relative harmony, of which the most harmonic is said to be the 'optimal' one. A tableau for representing this information takes the form outlined in (42) below, and we shall use its contents to explicate the form of optimality. The candidates, whose internal triple structure was discussed in 2.3.5, are for present purposes abbreviated to atomic alphabet symbols. All violations of constraints posted on the tableau are shown (by '\*'); just some of them are marked as crucial (by '!').

(42)

	C1	C2	C3	C4
a	**!	**		
b	*!	*		*
c		*!	*	
d			**!	*
e			*	*!
f			*	
g		*!	*	
h	*!			

Each constraint  $C_i$  is a function associating a string of violation marks (\*) to each candidate:

$C_i(x)$  is the string of marks associated with candidate  $x$ . Candidates are then ordered as to how many violation marks they incur:

(43) Let  $x$  and  $y$  be candidates, and  $C_i$  a constraint.

$x \prec^{C_i} y$  iff  $C_i(x)$  is longer than  $C_i(y)$

*$x$  is less harmonic than  $y$  with respect to constraint  $C_i$  if and only if  $x$  violates  $C_i$  more times than  $y$  does.*

Some pairs of candidates are not so ordered. For example, in (42)  $f$  and  $g$  are not discriminated by constraint  $C_1$ . Such pairs are equally harmonic or 'iso-harmonic' ( $f \approx g$ )<sup>27</sup>. The candidates fall into ordered equivalence classes of iso-harmony, {candidates with no marks}  $\succ$  {candidates with one mark}  $\succ$  {candidates with two marks}  $\succ$  ...etc.

Moving from column to column, the evaluation is cumulative. The higher-ranked constraints have priority in discriminating between candidates, and the lower-ranked constraints discriminate more and more candidates. Some candidates fair better than others, and only the best survive, the others suffering crucial violations (\*!) and they are shaded off for all subsequent columns. The overall harmonic ordering of the candidates in (42) is laid out in (44). Each line in (44) corresponds to evaluation against a portion of the hierarchy. The most harmonic candidates, which escape crucial constraint violations, are given in bold on the left.

---

<sup>27</sup>A reflexive, symmetric, transitive relation - an equivalence relation. The axiomatic properties are easily verifiable by consideration of the equivalence of having the same length of violation marks.

(44)

Portion of hierarchy considered	Overall relative harmonies
	abcdefgh
C1	<b>cdefg</b> $\succ$ bh $\succ$ a
C1>>C2	<b>def</b> $\succ$ cg $\succ$ bh $\succ$ a
C1>>C2>>C3	<b>ef</b> $\succ$ d $\succ$ cg $\succ$ bh $\succ$ a
C1>>C2>>C3>>C4	<b>f</b> $\succ$ e $\succ$ d $\succ$ cg $\succ$ h $\succ$ b $\succ$ a

Some harmony ratings are crucial to the non-optimality of the poorer-rated candidate:  $b \prec^{C1} c$ ,  $b$  is crucially violated by C1,  $c$  is not. Some are irrelevant to optimality:  $b \prec^{C4} h$ :  $b$  does have more C4 marks than  $h$ , but both crucially violate C1 anyway), and some are overridden ( $b \prec^{C4} a$ :  $b$  has more C4 marks –  $a$  has none, but  $a$  has more C1 marks and C1 is a higher constraint).

The ordering of relative harmony imposed by one constraint may be defined as in (45).

(45) Let ‘Cands’ be the set of candidates, and  $C_i$  a constraint. Then

$Eval_{C_i}(Cands) =_{\text{def}} \{ \langle x,y \rangle \mid x,y \in Cands \text{ such that } C_i(x) \text{ is longer than } C_i(y) \}$

*Eval<sub>C<sub>i</sub></sub>(Cands) is the ordering of candidates in relative harmony imposed by C<sub>i</sub>.*

Evaluation with respect to an entire constraint hierarchy  $\Gamma$  only admits ratings which do not contradict those imposed by higher-ranked constraints. This is defined in (46):

(46) Let  $\Gamma$  be a hierarchy of  $n$  ranked constraints  $C_1, C_2, \dots, C_n$

$\text{Eval}_\Gamma = \text{Eval}_{(n)}$ , where

$$\text{Eval}_{(i)} =_{\text{def}} \begin{cases} \text{Eval}_{C_1} & \text{if } i=1 \\ \text{Eval}_{(i-1)} \cup \text{Eval}_{C_i} / \text{Eval}_{(i-1)} & \text{if } i>1 \end{cases}$$

*Eval<sub>Γ</sub> accumulates from each constraint C<sub>i</sub> any discrimination in harmony between candidates not garnered from the higher constraints C<sub>1</sub>, ..., C<sub>(i-1)</sub>.*

The most harmonic candidates at each stage, which escape crucial violations in (42) and are presented in bold in (43), may be picked out as in (47):<sup>28</sup>

(47) (i) For each  $i$ ,  $\max(\text{Eval}_{(i)}) = \{ a : \neg \exists b \text{ such that } \langle b, a \rangle \in \text{Eval}_{(i)} \}$

*max(Eval<sub>(i)</sub>) is the subset of maximally harmonic candidates with respect to the hierarchy C<sub>1</sub>, ..., C<sub>i</sub>*

(ii)  $\max(\text{Eval}_\Gamma) = \{ a : \neg \exists b \text{ such that } \langle b, a \rangle \in \text{Eval}_\Gamma \}$

*max(Eval<sub>Γ</sub>) is the subset of maximally harmonic candidates with respect to the entire hierarchy – i.e. the optimal candidate(s).*

So while the derivational framework places structures in a sequence of which the end is the surface form, an OT grammar specifies harmony relationships between structures, of which the maximally harmonic candidate, or *optimal* candidate, contains the surface form for the underlying, input, form. How different harmony is from derivation remains to be examined.

<sup>28</sup>An alternative formulation is where filters for each of the constraints successively cream off the best of the best until all of the filters have been used and we are left with the optimal form (Eisner 1997a).

### 2.4.2 Optimality-Theoretic Constraints

Optimality-theoretic constraints are *violable*, but violation is *minimal* (McCarthy and Prince 1994:336). This appeals to a notion of *degree* of violation, spelt out by violation marks or the closely related harmony rating (no marks - rated top, 1 mark - rated next, etc.). An optimality-theoretic constraint C is a function from candidates (two structures in correspondence) to strings of \*'s. A fundamental issue is how to define linguistic constraints which register violation marks against candidates for each point at which they fail to meet some linguistic requirement.

In Optimality Theory, phonology is seen in terms of interactions among two kinds of constraints, Faithfulness constraints and Markedness constraints (Prince 1997a, McCarthy 2002). Faithfulness constraints require the correspondence relation between the two structures to conform to some property – essentially keeping input and output alike in some particular respect. Markedness constraints place requirements particularly on output structures themselves. Although other kinds of constraints have sometimes been countenanced (e.g. Archangeli and Suzuki 1997, McCarthy 1999a), they fall outside the core proposals of Optimality Theory and we shall leave them aside here.

We adopt the autosegmental view of phonological representations as graphs (Goldsmith 1976, Coleman and Local 1991, Bird 1995) and assume that correspondence relations exist between these graphs. In particular, phonological representations consist of several **nodes** which occupy a number of **tiers** in which all the nodes are of the same sort, a particular feature, or segmental root node, etc. On each tier the nodes are **ordered**, and nodes on different tiers are related by **association** (associations are also ordered). In the correspondence relation, the elements (nodes) on a particular tier in the input representation take correspondents on the equivalent tier in the output representation. In (48) we give a simple example of coindexing between input and output for tonal and melodic tiers.

(48)	Input:	Output:
	$H_a$ $/i \quad \backslash ii$ $b_1 a_2 n g_3 a_4$	$H_a$ $/i \quad \backslash ii$ $b_1 a_2 n g_3 a_4$

However, the “melodic tier” itself decomposes into a series of tiers for the segmental root and the various individual features. This view of correspondence then follows Lombardi (2001) and Zoll (1998) in assuming that Faithfulness constraints exist for all the feature tiers used in phonological representation.<sup>29</sup> Each feature tier  $\tau$  will have the following Faithfulness constraints:

(49)

a. MAXIMALITY $_{\tau}$  (MAX $_{\tau}$ ),

Every element in the input has a correspondent in the output.

b. DEPENDENCE $_{\tau}$  (DEP $_{\tau}$ )

Every element in the output has a correspondent in the input.

c. IDENTITY $_{\tau}$  (IDENT $_{\tau}$ )

Correspondent elements have identical values.

d. LINEARITY $_{\tau}$

The order of input elements is preserved among their output correspondents.

e. INTEGRITY $_{\tau}$

No element in the input has more than one correspondent in the output.

f. UNIFORMITY $_{\tau}$

No element in the input has more than one correspondent in the input.

---

<sup>29</sup> However, we should not postulate Faithfulness constraints on prosodic constituents (syllable, foot, etc.), since no such effects are observed (McCarthy 2003).

These constraints specify all the recognisable natural properties in the mathematics of relations. If all these properties are met on each tier within a representation and the output is *fully faithful* to the input, then we have an identity isomorphism between the tier structure in the input and the tier structure in the output. If on the other hand some property is not met, violation marks will be awarded for each exception to the property. For example, MAX will award violation marks for *each* input element that has no correspondent in the output. Further Faithfulness constraints may have linguistic motivation. Thus, McCarthy and Prince (1995) propose CONTIGUITY constraints (requiring preservation of the word- or morpheme-internal sequence without insertion or deletion) and ANCHOR constraints (requiring retention of initial and final elements).

We may now turn to Markedness constraints. Some Markedness constraints are defined by a structural configuration. Examples are given in (50).

- (50) LO/TR            'No [+low] feature is accompanied by a [+ATR] feature'  
 NONFINALITY 'No prosodic word ends with a foot edge'  
 NOGEMINATES 'No segmental root may be associated to two timing units'  
 OCP<sub>τ</sub>            'No adjacent identical elements on tier τ'

Candidates incur violation marks each time the output structure (not the input structure) contains this configuration, so with LO/TR, every instance in an output structure where [+low] and [+ATR] coincide warrants a violation mark. Other Markedness constraints have an implicational form, requiring that if some structural node (or possibly sub-configuration of nodes) is present, it is accompanied by another. Examples are given in (51):

- (51) NASVOI 'every nasal is accompanied by voicing'  
 ALIGN(PrWd,R,σ,R) 'the right edge of every word coincides  
 with the right edge of a syllable'  
 ONSET 'every syllable has an onset'

Every time the implication fails in the output structure, a violation mark is given. Thus, for ONSET, each syllable in an output structure that does not have an onset warrants a violation mark. These two simple schemes, negation and implication of certain structural configurations, cover typical proposals for Markedness constraints.<sup>30</sup>

Some Markedness constraints have been given a powerful facility of awarding different kinds of violation mark, some more severe than others. This would complicate the formulation of harmony evaluation given here; however, we would argue that this facility is superfluous. There are two contexts in which it has arisen. The first is in connection with natural phonological scales. HNUC (Prince and Smolensky 1993) marks syllable nuclei with increasing severity the lower down the sonority scale they are (low vowels > mid vowels > high vowels > approximants > nasals > voiced fricatives > voiceless fricatives > voiced plosives > voiceless plosives). However, as Prince and Smolensky (1993:81) observe, this can be replaced with a finite series of constraints for each sonority level: \*PEAK/voiceless plosives >> \*PEAK/voiced plosives >> \*PEAK/voiceless fricatives >> ... It is a general result that any constraint with a finite set of violation marks may be so reduced (Ellison 1994). This is shown in the text box below.

---

<sup>30</sup> Eisner (1997b) goes further and proposes that OT constraints be limited to specifying a negative or implicational relationship simply between a pair of structural elements or edges of constituents, such as 'syllable' and 'onset', or 'low' and 'ATR'.

**Reduction of a finite violation mark hierarchy:**

Suppose a constraint  $C$  produces  $N$  different kinds of marks,  $m_1, m_2, \dots, m_N$ , in increasing order of severity ( $m_1 \succ m_2 \succ \dots \succ m_N$ );

for each candidate  $c$ ,  $C$  determines a list  $C(c)$  of marks, concatenations not of \*'s but of  $\{m_i\} (1 \leq i \leq N)$ .

To separate out each kind of mark, let  $f_1(C(c))$  be the string containing only the marks  $m_1$  from  $C(c)$ , and define  $f_i$ ,  $i=2, \dots, N$  similarly;

$C$  can be replaced by binary constraints  $C_1, C_2, \dots, C_N$  such that  $C_i(c) = f_i(C(c))$ , so that each mark type is taken over by a separate constraint. Just as a mark  $m_2$  is more costly to a candidate than a mark  $m_1$ , violation of  $C_2$  is concomitantly more costly than  $C_1$ , and adoption of the ranking  $C_2 \gg C_1$  captures precisely this. In general, the mark hierarchy  $m_1 \succ m_2 \succ \dots \succ m_N$  is converted to the ranking  $C_N \gg \dots \gg C_1$ , a hierarchy of constraints each assigning strings of a single mark.

The second place where severity of violation has been used does not give a finite hierarchy of marks. The Tagalog affix *-um-* appears as a prefix as in *um-aral* 'teach' provided that *m* is not parsed in a syllable coda position (V\_\_C). If this cannot be met, then it infixes as close to the left as possible: *gr-um-adwet* \**um-gradwet* 'graduate' (McCarthy and Prince 1993a:101). The pattern is analysed using the constraint NOCODA, 'every syllable has no coda' ranked above  $\text{ALIGN}([um]_{\text{Af}}, L, \text{Stem}, L)$ , 'the left edge of every *um* affix coincides with the left edge of a stem' (the root and *um* affix together constitute a stem). A tableau for the infixed Tagalog form for 'graduate' is given in (52).

(52)

/um/,/gradwet/	NOCODA	ALIGN- <i>um</i>
a. [ <b>um</b> .grad.wet.	***!	
b. [g- <b>um</b> .rad.wet.	***!	*(1)
c. [gr- <b>u</b> .mad.wet.	**	*(2)
d. [grad.w- <b>u</b> .met.	**	*(5)!

In candidates b.,c.,d. the affix is misaligned and so violates ALIGN-*um*. But it does so with increasing severity because of the increasing distance from the left edge of the stem. Once candidates a.,b. are eliminated by the other constraint NOCODA, the choice between c. and d. is settled purely on the fact that the misalignment in c. is less severe than that in d. This cannot be replaced by a hierarchy of constraints because the distance of misalignment depends on the number of segments in a stem, and this is not bounded – phonological structures are of arbitrarily length. There is however, another solution, namely that we reformulate the constraint as a generalisation about intervening material (Ellison 1994, Zoll 1998):

(53) NOINTERVENING:Segments([um],L,Stem,L) = 'Given an *um* affix, there is a stem such that no segments intervene between the left edges of the two'

This simply associates two violation marks \* \* to /gr-**u**.mad.wet./ for the segments *gr* and five violation marks \* \* \* \* \* to /grad.w-**u**.met./ for the segments *gradw*, in the normal way. While Ellison (1994) and Zoll (1998) appear to implicitly assume such constraints generalise over segments, other NOINTERVENING constraints might generalise over another structural entity,

such as the syllable, the feature [+nasal], etc.<sup>31</sup> This reformulation shows that constraints of alignment which incorporate marks of unbounded severity do reduce to constraints which use \*'s, again preserving the formalisation of harmony evaluation already given.

In general, as we showed, a finite hierarchy of marks can be reconstructed with constraints employing a single string of marks; the difficulty comes when there is no bound on the possible severity of violation, since one could not then generate a set of constraints to replace the degrees of severity. The source of motivation for such a constraint is limited, however: any set of marks motivated by scales within substantive phonological theory will be finite, e.g. prosodic hierarchy, feature dependencies, sonority hierarchy, markedness hierarchies. Phonetic scales referring to articulatory or acoustic dimensions are infinite, but in practice it appears that only a certain list of threshold values are relevant to phonological analysis (e.g. Kirchner 1996). Unboundedness in phonology arises instead in the arbitrarily large size of phonological structures. This offers the possibility that constraints may have a severity of violation that increases with the size of a structure. Such constraints (such as constraints of constituent alignment) must have a unit of measurement of severity such as the segment or syllable. We know that alignment constraints of this kind reduce to generalisations on the structural element used as the unit of measurement, and other generalisations of similar complexity (unreported, but perhaps requirements of adjacency or licensing are abstract possibilities) are likely to reduce the same way. These considerations leave the window of plausible constraints with irreducible unbounded sets of violation marks vanishingly small.

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<sup>31</sup> McCarthy (2002b) proposes that it is *prosodic constituents* such as the syllable or foot that are prohibited from intervening between two boundaries in a representation.

### 2.4.3 The Structure of Optimality Theoretic Grammar

The specification in (54) now outlines optimality-theoretic grammars.

(54) An Optimality-theoretic grammar is a quintuple  $\langle P, Un, Corr, \Gamma, Eval_{\Gamma} \rangle$  where:

$P$  is the set of possible phonological structures

$Un$  is a finite set of phonological structures

$Corr: in \rightarrow \langle in, P, in \times P \rangle$  is a function which takes a phonological structure  $in$  as an input and associates with it triples  $\langle in, p, in \times p \rangle$  for all phonological structures  $p$  and for each  $p$ , all correspondence relations between  $in$  and  $p$ . These are the candidates for a phonological input.

$\Gamma = \langle CON, \ll \rangle$ , a set of constraints  $CON$  with an ordering  $\ll$ , where the constraints are functions which associate a string of \*'s to triples  $\langle in, p, in \times p \rangle$ .

$Eval_{\Gamma}$  defines an ordering  $\prec$  on triples  $\langle in, p, in \times p \rangle$  from  $\Gamma$ .

This means that surface forms are determined as follows. For any underlying representation  $un$  in

$Un$ :

→ The candidates are the set of triples given by  $Corr(un)$  – all structures in all correspondences to  $un$

→ The candidate triples are ordered by  $Eval_{\Gamma}(Corr(un))$  – the harmony scale

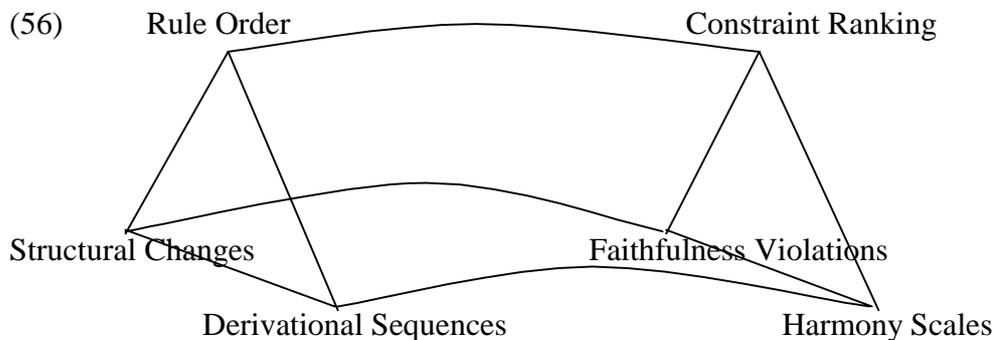
→ The optimal triple (or triples) is picked out by  $\max(Eval_{\Gamma}(Corr(un)))$

→ The second member of this triple (or triples) is the corresponding surface representation.

## 2.5 Programme For Structural Comparison

We have a rule-based generation system in the derivational framework (constraints being underformalised and eliminable) and a constraint-based evaluation system in the optimality framework (generation being redundant).

A generation system and an evaluation system which generate the same surface forms from the same underlying forms describe the same function. A generation system and evaluation system which describe the same function are comparable in structure at three points:



Rules are comparable to Constraints in that Structural Descriptions and Structural Changes of rules are comparable with Markedness / Faithfulness interactions, and the fact that an ordering relation is defined on both rules and constraints. And the derivational sequences of structures, the last of which is the surface form, is comparable with the relative harmony of structures, of which the most harmonic is the surface form. These three structural analogies provide the basis for comparative studies of the frameworks, which we will pursue in the next three chapters.

## CHAPTER 3:

### THE UNDERLYING FORM – SURFACE FORM CORRESPONDENCE

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Between underlying and surface representations, some pieces of structure are the same and are arranged in the same way, held constant by the grammar; other pieces fail to be so, being modified by the grammar. That is, there is a map between the underlying structure and surface structure, which we may call the **underlying-surface correspondence**.<sup>32</sup> In this chapter we compare the two formal approaches to this map: in derivational theory, the underlying form is mapped to the surface form by the operations of rules; in optimality theory, the underlying form is mapped to the surface form by the input-output correspondence relation, which may register violations of Faithfulness constraints.

We show that the complexity of the derivational approach is greater, because some steps of a derivation may be obscured in the overall mapping, but it is always possible to construct a derivation whose overall mapping is **representative** of all its steps. We then identify a more restricted natural class of **veritable** mappings, showing how this property is approximated by the **minimality of constraint violation** metric in Optimality Theory (Pulleyblank and Turkel 1997), and by the principle of **economy of derivation** in Minimalist derivational theory (Calabrese 1995). Finally, we use this formal analysis to explain phonologists' long-standing suspicion of the so-called Duke of York gambit, and we clarify the issue with fresh arguments that the Duke of York gambit is both unexplanatory in general and contrary to the empirical evidence.

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<sup>32</sup> We assume, after Goldsmith (1976), Coleman and Local (1991) and Bird (1995), that the structures concerned are *graphs* with a "multi-linear" arrangement of several linear sequences (*tiers*) of *nodes* specified with features or other phonological units, and ordered *associations* between nodes on different tiers.

### 3.1 Rule Operations and Faithfulness Constraint Violations

The basis for a systematic comparison lies in the fact that the types of operations used in structural changes in a derivation and the violations of Faithfulness constraints in an evaluation system may be identified with the same basic set of formal mappings. When a Deletion operation occurs in a derivation, there is some piece of structure in one representation (the **focus**) which is not mapped to anything in the subsequent representation. Similarly, a violation of the constraint MAX occurs precisely when an input-output correspondence contains a piece of structure in the input that is not mapped to anything in the output. So an essential analogy exists between Deletion and MAX violation, for in both instances, there is some structural object that is not mapped to any object. This is a matter of mathematical fact, a breach of the relational property of *totality*. Totality holds when *every* object in the domain is mapped to some object in the range. Similar analogies exist between other rule operations and Faithfulness constraints:

(1)

Disparity	Rule Operation	Faithfulness Violation
$x \rightarrow \emptyset$	Deletion	MAX violation
$\emptyset \rightarrow x$	Insertion	DEP violation
$x_1 \rightarrow x_1 x_1$	Fissure	INTEGRITY violation
$x_1 x_2 \rightarrow x_{12}$	Fusion	UNIFORMITY violation
$x \rightarrow y$	Change of Value	IDENT violation
$xy \rightarrow yx$	Change of Order	LINEARITY violation

Furthermore, any disparity, whether it is viewed as the application of some operation, or as the violation of some Faithfulness constraint, essentially boils down to a breach of one of the stock

properties used to describe the behaviour of mathematical relations, defined in (2) (Partee, ter Meulen and Wall 1990:27ff):

(2)

Disparity	Property Breached	Property holds when...
$x \rightarrow \emptyset$	totality	every object mapped to some object
$\emptyset \rightarrow x$	surjectivity	every object mapped from some object
$x_1 \rightarrow x_1 x_1$	function	no object mapped to more than one object
$x_1 x_2 \rightarrow x_1 x_2$	injectivity	no object mapped from more than one object
$x \rightarrow y$	identity	every object mapped to an identical object
$xy \rightarrow yx$	structure preservation	all objects mapped to objects with same order as the original

Thus, the analogy between rule operations and Faithfulness constraint violations is grounded in the theory of mathematical relations.

### 3.2 Input-Output Correspondence and Derivational History Relations

The next question is how the disparities combine into an overall mapping. In this section, we consider how this is done in each framework, demonstrating that the complexity of the derivational framework is greater.

#### 3.2.1 Input-Output Correspondences

In an evaluation system, we know from chapter two that for a given underlying form  $I$ , all the candidate-triples  $\langle I, O, C \rangle$  (where  $O$  is any structure and  $C$  is any correspondence relation

between I and O) are in principle subject to evaluation, and that the system delivers one optimal candidate  $\langle I, O_{opt}, C_{opt} \rangle$ . Thus, in an evaluation system, the underlying-surface correspondence is an input-output correspondence - specifically, the input-output correspondence of the optimal candidate,  $C_{opt}$ .

As well as all other structures  $O_{subopt}$  being ruled out, all the other possible correspondence relations for  $O_{opt}$  are ruled out as the underlying-surface correspondence. That is, a candidate  $\langle I, O_{opt}, C_{subopt} \rangle$  which contains the same output form  $O_{opt}$  but assumes a different correspondence relation  $C_{subopt}$  will be non-optimal and thus  $C_{subopt}$  is not the underlying-surface correspondence. So taking the simplest case when the surface representation is the same as the underlying representation, the evaluation selects the identity relation rather than some more complex mapping. This is shown in (3) for the mapping  $/bi/ \rightarrow [bi]$ .

(3)

	/bi/	MAX	DEP	IDENT	LINEARITY
a.	Input: /b <sub>1</sub> i <sub>2</sub> / Output: [b <sub>1</sub> i <sub>2</sub> ]				
b.	Input: /b <sub>1</sub> i/ Output: [b <sub>1</sub> i]	*	*		
c.	Input: /bi <sub>2</sub> / Output: [bi <sub>2</sub> ]	*	*		
d.	Input: /b <sub>1</sub> i <sub>2</sub> / Output: [b <sub>2</sub> i <sub>1</sub> ]			**	*

Hence, in the optimality framework, the underlying-surface correspondence is none other than the input-output correspondence of the optimal candidate. It is selected by evaluation against the constraints.

### 3.2.2 Derivational History Relations

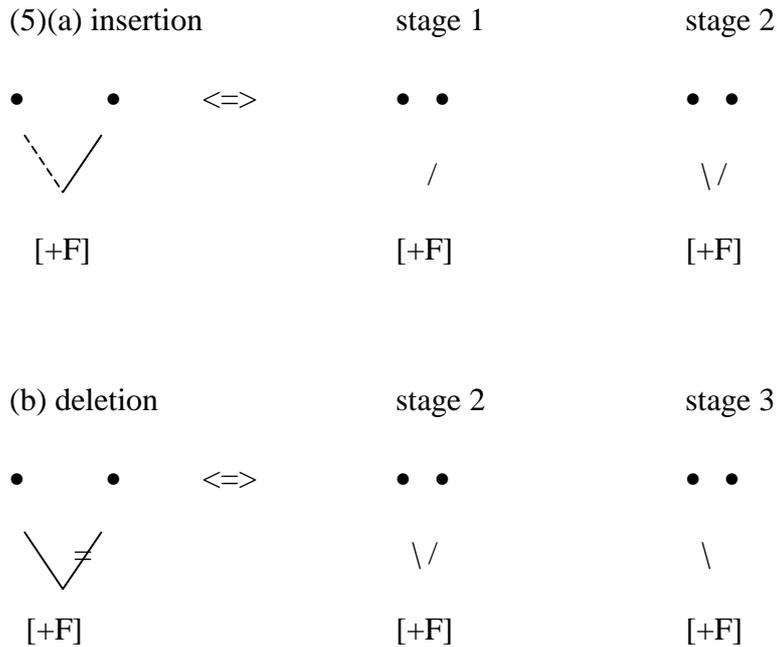
In the derivational framework, an underlying-surface correspondence is constructed from a whole series of structure-to-structure mappings in a derivation. The **serial composition** of these mappings is a construct that matches in form the input-output correspondence of an evaluation.

Consider for example a case where a feature spreads (indicated in (4) by the dotted line) leftwards to a new anchor node and delinks (indicated in (4) by double-crossed line) from the original anchor node:



A concrete instance of this is the Klamath alternation presented in 1.2, where lateral articulation is realised on one segment to the left of that where it is given underlyingly: /n-ɺ/ sequences become [lh] and /nɺ/ sequences become [lʔ]. This is a leftward shift in the association of a [+lateral] feature.

The usual notations for spreading and delinking (association lines dotted or crossed out, respectively) are useful connotations of the relation between successive structures in a derivation. (4) abbreviates a derivation in which there are three stages: between the first and second stages, an operation applies inserting an association between [+F] and the first anchor (●); between the second and third stages, an operation applies deleting an association between [+F] and the second anchor. (5a.) illustrates the insertion (spreading), (5b.) illustrates the deletion (delinking).



Call each of the two subsequences from stage 1 to stage 2 and from stage 2 to stage 3 a **step**.

Call the mapping between stage 1 and stage 2 “ $_1\text{step}_2$ ”, and call the mapping between stage 2 and stage 3 “ $_2\text{step}_3$ ”. These separate steps somehow combine to give the situation summarised in (4) with two underlying/surface disparities. In fact, this is achieved by serial composition.

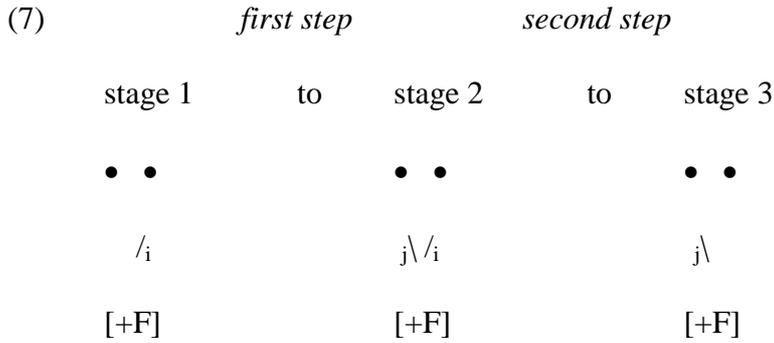
(6) **Definition: Serial Composition** (Partee, ter Meulen and Wall 1990:35)

For sets A,B,C, and relations R between A and B, and S between B and C, the serial composition of R and S, a relation between A and C, is given by:

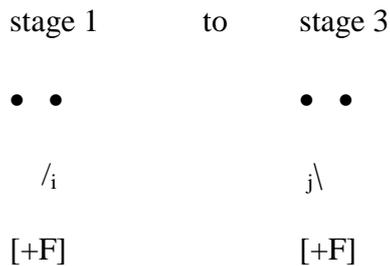
$$S \circ R =_{\text{def}} \{(x,z) \mid \exists y \text{ such that } (x,y) \in R, (y,z) \in S\}$$

*The serial composition of two mappings relates elements in the first structure to elements in the last structure that are indirectly linked via the second structure.*

This we can illustrate in (7): the composite relation of the two mappings  ${}_1\text{step}_2$  and  ${}_2\text{step}_3$  matches items at stages 1 and 3 which are indirectly linked via some intermediate element at stage 2 according to the respective relations  ${}_1\text{step}_2$  and  ${}_2\text{step}_3$ .



composite relation:



The association inserted in the first step (coindexed  $j$ ) is present at the final stage but this lacks a correspondent at the initial stage. The association deleted in the second step (coindexed  $i$ ) is present at the initial stage but this lacks a correspondent at the final stage. In this way the composite relation identifies the two associations as having been inserted or deleted in the course of the derivation.

The application of any rule has a characteristic correspondence relation, exhibiting a breach of some relational property according to what kind of operation is applied (as tabulated in (2)). These characteristic "step"-relations may be composed in series to produce long-range correspondences that relate back structural elements at any stage to their antecedents in the first

structure. Such relations express **derivational histories**, a notion already named and discussed in the generative phonology literature (Kenstowicz and Kisseberth 1977). While  ${}_1\text{step}_2$  links the structure at the second stage back to that of stage 1,  ${}_2\text{step}_3 \circ {}_1\text{step}_2$  now links the structure of the third stage back to stage 1. This leads us to a general definition:

(9) **Definition: Derivational History Relation**

Let the structures at stages 1,2,...,n of a derivation be denoted  $P_1, P_2, \dots, P_n$ . Let the correspondence mapping characteristic of the rule which applies at each step  $\langle P_i, P_{i+1} \rangle$  be  ${}_i\text{step}_{i+1}$ . The **derivational history relation** of each structure  $P_i$ :

a.  ${}_1H_2 =_{\text{def}} {}_1\text{step}_2$

*The derivational history relation between the structure at stage 2 and the initial structure is simply the step relation between stages 1 and 2.*

b. for  $i \geq 3$ ,  ${}_iH_i =_{\text{def}} {}_{i-1}\text{step}_i \circ {}_{i-1}H_{i-1} = \{ \langle x, z \rangle \mid \text{for some } y, \langle x, y \rangle \in {}_{i-1}H_{i-1} \text{ and } \langle y, z \rangle \in {}_{i-1}\text{step}_i \}$

*The derivational history relation between the structure at stage i and the initial structure links elements in the structure that are linked indirectly via the derivational history of the structure at stage i-1 and the step from i-1 to i.*

Equivalently, the derivational history relation  ${}_iH_i$  can be viewed as the serial composition of all the successive step-relations for the steps between stage 1 and stage  $i$  as given in (10).

(10)  $i=2, \dots, n$ ,  ${}_iH_i =_{\text{def}} ({}_{i-1}\text{step}_i \circ ({}_{i-2}\text{step}_{i-1} \circ \dots ({}_2\text{step}_3 \circ {}_1\text{step}_2) \dots))$

Since the composition is defined step by step, the earliest derivational steps are given in the most nested position (on the right in (10)) and the later derivational steps in the least nested position.

Having defined the derivational history relation for an entire structure, we can recognise the derivational history of a particular entity within a structure (Kenstowicz and Kisseberth 1977). The derivational history of a particular entity  $z$  within the structure at stage  $i$  of the derivation is any ordered pair  $\langle z_1, z \rangle$  within  ${}_1H_i$  relating  $z$  back to some object  $z_1$  in the first structure. But if the object owes its presence to an insertion operation, there will be no such statement and its derivational history is null.

Finally, we observe that in a derivation totalling  $n$  stages, the derivational history relation  ${}_1H_n$  relates the last structure back to the first structure. Hence, the underlying-surface correspondence as given by a derivational grammar is the relation  ${}_1H_n$  in the particular derivation concerned.

### *3.2.3 Identifying The Two*

In both frameworks we can relate structural components back to those in the underlying structure, either by input-output correspondences or by serial composition of the mappings at each step of a derivation.

A generation system and an evaluation system describing the same function from a set of underlying forms and a set of surface forms may agree with each other as to the underlying-surface correspondences. They do so if the final derivational history relations and the optimal input-output correspondences are identical: if, in every case,  ${}_1H_n = C_{opt}$ .

They differ, of course, on how these correspondences are constructed. If there are  $n$  disparities in an underlying-surface correspondence, they will be contained in the input-output correspondence of the optimal candidate. But a derivational history relation with those  $n$  disparities is composed serially. Each may be introduced step by step in a series of  $n$  operations. These  $n$  steps produce the same final structure whatever order they are placed in, and the number of possible orders is the number of permutations of  $n$ , given by the formula

$$(12) \quad n! = n.(n-1).(n-2)....2.1 \quad \text{e.g. } 4! = 4.3.2.1 = 24$$

So there is a natural class of  $n!$  possible derivations which could be responsible for an underlying-surface correspondence relation containing  $n$  disparities.

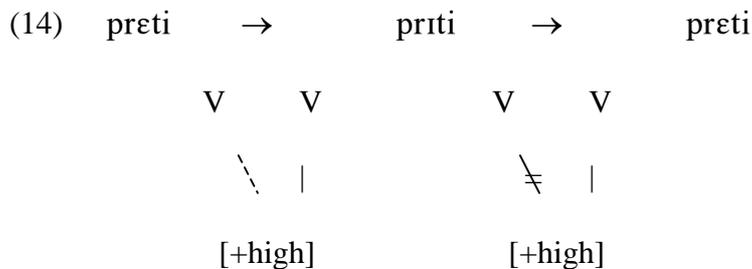
### 3.2.4 Hidden Operations

In derivations specifically, however, some operations may be obscured by subsequent operations and not be apparent in the final derivational history relation. This possibility adds considerably to the class of  $n!$  natural derivations that could be responsible for a given underlying-surface correspondence.

We pursue this by means of an example. In many dialects of Italian, there is a metaphony process where mid vowels are replaced by high vowels in the presence of a following high vowel. The vowels that are raised are stressed vowels, in the first syllable of the last foot in a word (Calabrese 1995:450). The examples in (13) are from the Veneto dialect. The metaphony process can be detected in the examples (13a), where it affects "tense", or ATR, vowels. However, metaphony is not apparent in the examples in (13b) where the vowel is "lax"/nonATR:

- (13) Veneto Italian (Calabrese 1995:446)
- |    |       |         |                  |
|----|-------|---------|------------------|
| a. | védo  | te vídi | I see / you see  |
|    | córo  | te cúri | I run / you run  |
|    | tóso  | túsi    | boy / boys       |
| b. | préte | préti   | priest / priests |
|    | módo  | módi    | way / ways       |

If the vowels in (13b) were to undergo metaphony, the high nonATR vowels ([ɪ,u]) would be produced, universally marked vowels which in many languages would not be realised on the surface, but substituted for by other, unmarked vowels. Thus, in some other Italian dialects the vowels [i,u] are found in this context (neutralising with ATR vowels); one further dialect has [e,o]. In the Veneto Italian dialect, then, it appears that the repair *lowers* the vowels to [ɛ,ɔ]. However, we then end up with an analysis in which the [+high] feature of the following vowel is spread to the head vowel only to be delinked again:



This is an instance of the so-called Duke of York gambit, where one structural change is reversed by the opposite change (Pullum 1976). In fact, in the overall derivational history relation we simply have no trace of these steps. If there were an association present in the surface form but not in the underlying form, this would evidence the insertion of the association since we would have a piece of structure at the last stage lacking a historical antecedent at the first stage, but here no association line is present either in the surface form or the underlying form, so that no operations are implicated at all. The spreading and delinking operations are not apparent in the overall derivational history relation - *it is just as if they had not applied*.

The alternative, as eventually chosen by Calabrese (1995), is to adopt an analysis of this dialect where the steps in (14) are not used, where the metaphony rule is more strongly restricted so as to spread the [+high] feature only to ATR target vowels, and not to nonATR target vowels.

Then the derivational history relation is a true account of the derivation, there being no "hidden" spreading and delinking.

In fact, as we now demonstrate, whenever the entity produced by one operation is itself subjected to another operation, the form of these two operations becomes obscured in the derivational history relation. This is what happens with several kinds of Duke of York gambit, as in (15). We shall examine some other Duke of York gambits, that have a different effect, in 3.3.3.

(15) Obscured Duke of York gambits

- Inserted elements may subsequently be deleted again.

stepwise	$\emptyset \rightarrow a \rightarrow \emptyset$
overall	$\emptyset \rightarrow \emptyset$

- Fissured elements may subsequently be re-fused.

stepwise	$a \rightarrow aa \rightarrow a$
overall	$a \rightarrow a$

- Value changes may subsequently be subject to a reverse value change.

stepwise	$-F \rightarrow +F \rightarrow -F$
overall	$-F \rightarrow -F$

- Order change may be subject to a reverse order change.

stepwise	$ab \rightarrow ba \rightarrow ab$
overall	$ab \rightarrow ab$

There are other combinations that serve to obscure operations in a derivation. All deletion of objects previously changed by other operations, and all changes to inserted elements have this effect:

(16) a. Value change and Deletion:

stage	stepwise		overall	
1	-F		-F	
2	+F	Value Change		
3	∅	Deletion	∅	Deletion (Value Change obscured)

b. Insertion and Value change:

stage	stepwise		overall	
1	∅		∅	
2	-F	Insertion		
3	+F	Value Change	+F	Insertion (Value Change obscured)

c. Others

Order change and Deletion: Insertion and Order change:

stage	stepwise		overall		
1	a b	a b	a	a	
	X				
2	b a		a b		
			X		
3	a	a	b a	b a	(order changes obscured)

Fusion and Deletion:			Insertion and Fusion:		
stage	stepwise	overall	stepwise	overall	
1	a b	a b	a	a	
	∨				
2	c		a b		
			∨		
3	∅	∅	c	c	(fusions obscured)

Fissure and Deletion:			Insertion and Fissure:		
stage	stepwise	overall	stepwise	overall	
1	a	a	∅	∅	
	∧				
2	b c		a		
			∧		
3	b	b	b c	b c	(fissures obscured)

Furthermore, just as deletion and insertion obscure other operations on the deleted or inserted elements in (16), so also fusion obscures previous operations on the fused entities, and operations on entities coming from a fissure operation obscure the nature of the fissure. These are all the possible cases where an entity placed by one operation is itself the subject of another operation: each time, the steps are obscured in the overall mapping.

### 3.2.5 Representative Derivational History Relations

It is, then, in the nature of mapping over a series of steps that some operations may not be apparent in the final derivational history relation. It is useful to define a property of representativity that excludes this possibility:

#### (17) **Definition: Representativity of Correspondence under Serial Composition**

- a. For sets  $A, B, C$ , and relations  $R: A \rightarrow B$ , and  $S: B \rightarrow C$ , the serial composition  $S \circ R =_{\text{def}} \{ \langle x, z \rangle \mid \exists y$   
such that  $\langle x, y \rangle \in R, \langle y, z \rangle \in S \}$  is **representative of S and R under serial composition** if and only if all and only those disparities in  $R$  or  $S$  are also disparities in the  $S \circ R$  mapping.

*The serial composition of two mappings is representative if and only if all the disparities in the two individual mappings are visible in the overall mapping.*

- b. We shall also require the representativity property to be cumulative, so that given a further relation  $T:C \rightarrow D$ , the serial composition  $T \circ (S \circ R)$  is **representative of T, S and R under serial composition** if and only if (i) it is representative of T and SoR under serial composition and (ii) SoR is itself representative of S and R under serial composition.

*The serial composition of several mappings is representative if and only if all the disparities in each of the individual mappings are visible in the overall mapping.*

This definition means that for a derivation of  $n$  steps, where  ${}_1\text{step}_2, {}_2\text{step}_3, \dots, {}_{n-1}\text{step}_n$  are the mappings at each step, the overall derivational history relation (18) is representative of the mappings at all the steps if and only if it contains the disparities that are present in all the mappings,  ${}_1\text{step}_2, {}_2\text{step}_3, \dots, {}_{n-1}\text{step}_n$ .<sup>33</sup>

(18) Overall Representative Derivational History Relation

$${}_1H_n = {}_{n-1}\text{step}_n \circ \dots \circ {}_2\text{step}_3 \circ {}_1\text{step}_2$$

Which derivations produce representative derivational history relations? Not those where an element produced by one operation is altered by another operation, for that leads to obscuring of the operations. Rather, derivations are representative when the rule operations in them alter elements of the structure in *different* parts of the structure (or more precisely, elements with distinct derivational histories). So representativity is co-extensive with the class of derivations in

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<sup>33</sup> Unlike the basic definition in (10) in which composition proceeds in a properly nested fashion, the order of composition becomes irrelevant under representativity, and (18) reflects this. That is, for representative serial compositions, the serial composition operation is *commutative*.

which no rule may alter the material introduced by the structural change of another rule.

Derivations conforming to this restriction we may call **cumulative derivations**.

Cumulative derivations still include some subtle rule combinations. For example, a feature change followed by metathesis is admissible because one changes the identity of the feature itself while the other changes an ordering statement for the feature tier:

$$(19) \quad \begin{array}{l} -F_i -F_j \\ \quad \times \\ -F_j +F_i \end{array}$$

Note that a phoneme segment may be affected more than once in a cumulative derivation, provided each *feature* is affected only once, since these are the formal objects of the phonological representation to which the cumulative restriction applies. The alternants [d]-[s]-[ʒ] in *decide-decisive-decision*, *evade-evasive-evasion*, *corrode-corrosive-corrosion*, display processes of spirantisation and palatalisation of the underlying /d/, but voicing alternates also (Chomsky 1995:224, Chomsky and Halle 1968:229ff). /d/ spirantises and devoices before the suffix *-ive*, so we might seek to apply these processes again before *-ion*, and then voice the fricative again for *decision*, etc. by the /s/-voicing rule of English (Chomsky and Halle (1968:228), cf. *gymnasium* [dʒɪmneɪziəm]). However, a cumulative derivation that starts with [+voice] will either keep it or devoice, but not revoice. Chomsky and Halle's chosen analysis conforms to this, since they derive [ʒ] in *decision* from /d/ by spirantisation and palatalisation as in (20). Devoicing applies with the *-ive* suffix and with a few other derivatives of verbs: *saye* → *safe*, *use* → *usage*, but not with *-ion* (Chomsky and Halle 1968:232).

(20) Abbreviated derivation of *decisive* and *decision*

dəsaɪd ɪv	dəsaɪd iən	
z	ʒ	Spirantisation (stem-final alveolars)
	ʒ	Palatalisation (of <u>C</u> iV)
s		Devoicing (stem-final fricatives)

## 3.2.6 Summary

Building on the analogy in 3.1 between rule operations and Faithfulness constraint violations, we have shown that the relation of derivational history is, formally speaking, the derivational counterpart to input-output correspondence relations.

We have shown that the application of operations in series is more complex than the violations of Faithfulness constraints in input-output maps, because one rule operation can change an object created by another operation. This leads to a derivational history relation that is not representative of all the steps. By contrast, input-output correspondences are always representative of themselves – a degenerate case of representativity. In **cumulative** derivations, however, no operation changes an object created by a previous operation. The derivational history relation is representative of all the steps, and so these derivations are no more complex than input-output correspondences. An input-output correspondence relation with  $n$  Faithfulness violations correlates with the class of  $n!$  possible cumulative derivations containing the analogous  $n$  operations and no others.

We go on to consider a more restricted range of correspondences.

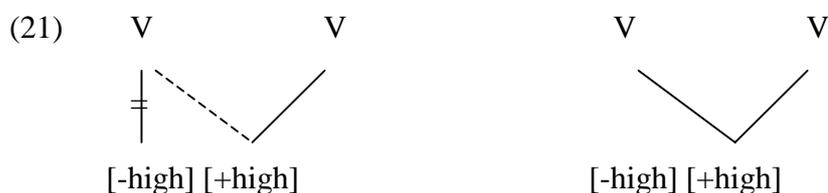
### 3.3 Natural Correspondences

Even when hidden operations are ruled out, there are many ways a given pair of underlying and surface structures might correspond. For example, a mapping from  $ab$  to  $ba$  could be construed as a total relation with a reversal of order of the elements, or it could be construed as an empty relation in which the  $a$  and  $b$  in the final structure bear no relation to the  $a$  and  $b$  in the original structure. Still other relations are logically possible. This raises the question as to whether we can pick out the most natural correspondences, and whether we can constrain generation systems and evaluation systems so that only the natural correspondences are obtained.

#### 3.3.1 Veritable Correspondence

Consider again the example from Veneto Italian from 3.2.4. A vowel-raising-and-lowering derivation like  $\text{préti} \rightarrow \text{príti} \rightarrow \text{préti}$  is complex specifically in that it does not provide the most natural underlying-surface correspondence.

The raising of mid vowels in stress position (head vowel of the rightmost foot) is achieved by the leftward spreading of a [+high] feature. Now this is accompanied by the delinking of the [-high] feature originally associated to that vowel - that is, the deletion of the association between it and its anchor, as in (21):



In derivations of words with non-ATR vowels like  $\text{préti} \rightarrow \text{príti} \rightarrow \text{préti}$ , raising of stressed mid vowels would produce the vowel /i/, which being unattested in the language, will be the subject of a repair which in this dialect would reverse both operations: the [+high] feature must

be delinked again (the inserted association must be deleted) and also the [-high] feature must be re-linked to the head vowel (an association must be inserted), as shown in (22).<sup>34</sup>



The deletion of a previously inserted association line (the spreading and delinking of [+high]) was discussed in 3.2.4, but we also have *insertion* of material identical to that *previously deleted* (delinking and relinking of [-high]). Now despite the Duke-of-York character of this derivation, the derivational history relation is perfectly representative here: the underlying V~[-high] association and the surface V~[-high] association do not correspond to each other, as illustrated in (23a), where they are indexed differently (2 and 4), representing the fact that the grammar removes an association and adds an association.

(23)

	a. Insertion-&-Deletion mapping	b. Natural mapping
Underlying	$V_1$ $ _2$ $[-high]_3$	$V_1$ $ _2$ $[-high]_3$
	↓	↓
Surface	$V_1$ $ _4$ $[-high]_3$	$V_1$ $ _2$ $[-high]_3$

<sup>34</sup> There is indeterminacy as to how the spreading/delinking/relinking/delinking derivation would actually work. Once the [+high] first spreads in (21), does the [-high] delink to remove the anomaly of the dual specification for height as occurs in the simpler case of ATR vowels as we have assumed, or does the [+high] now delink again without delinking the [-high]? Or do both delink simultaneously? Or does [-high] delink before all other operations? Or simultaneously with the original spread of [+high]? There is nothing to go on to decide.

The one in (23b) represents the situation in which nothing is changed between underlying and surface forms, this reflected in the coindexing of all parts (1,2,3), including the association line. The mapping in (23b) eliminates two gratuitous disparities at a stroke from the underlying-surface correspondence: the lack of a surface correspondent to the underlying association, and the lack of an underlying correspondent to the surface association. In Veneto Italian, for example, this is achieved by adopting an analysis in which the raising rule is formulated so as not to delink [-high] in the first place if the vowel is [-ATR].

Whereas (23a) is subtle and surprising, (23b) is natural and expected. Why? Because it expresses a visible similarity. To give it a name, it is a "**veritable**" correspondence, expressing the similarities that are apparent between the two sub-structures. A veritable correspondence has just those disparities necessary to express the discrepancies, and none that would fail to express the similarities: it has a *minimum* of disparities. A veritable correspondence is not the same as a faithful correspondence in optimality theory. The usefulness of the term *veritable* lies in the fact that two structures may not be identical - so that there is no fully faithful correspondence between them - but there will still be a veritable correspondence between them, the one with the minimum of disparities. This allows us to express *how similar* structures are. How this works out precisely we now examine in the context first of the optimality framework, then of the derivational framework.

### 3.3.2 *Minimal Violation of Faithfulness Constraints*

In optimality theory, the minimisation of disparities amounts to the minimisation of Faithfulness constraint violations. According to the core Optimality-Theoretic principle of Violability (McCarthy and Prince 1994:336), constraints are violable in optimality theory, but *minimally*: only in order that higher-ranked constraints may be satisfied (or at least violated less seriously themselves). In particular, then, minimal violation applies to the Faithfulness

constraints. And if Faithfulness constraints are violated minimally, disparities between underlying and surface structures will be minimised, so that candidates with veritable correspondences will be preferred.

For example, for each underlying form there will be candidates that employ input-output correspondences with complementary MAX and DEP violations between objects that happen to be identical in value and position, but such candidates will always be less harmonic than those with the veritable correspondence which lacks these violations. (24) evaluates correspondences between identical entities in the input and output: in candidate *a.* the *x*'s are not in correspondence, in *b.* they are.

(24)

		/..x../	IDENT	LINEARITY	MAX	DEP
a.	Input	x				
	Output	x			*	*
b.	Input	x				
	Output	x				

There is no constraint for which (24a) is more harmonic than (24b) - the Faithfulness constraints unambiguously prefer (24b), and no output constraint discriminates between them. (24a) is always less harmonic than (24b) whatever the ranking of constraints. It is therefore unoptimisable in a system that evaluates correspondence relations by Faithfulness constraints<sup>35</sup>, a fact we represent here by shading not only the crucial violation marks but the candidate itself.

<sup>35</sup>It would be optimisable in a system which includes "anti-Faithfulness" constraints that *require* disparities.

Minimising the lack of correspondents as in (24) is counterbalanced by the similar avoidance of gratuitous multiple correspondents. Multiple correspondents violate the Faithfulness constraints INTEGRITY and UNIFORMITY. Candidates with complementary violations of these constraints are always less harmonic than candidates without the offending multiple correspondents. Hence, candidates a. and b. in the illustrative tableau (25) can never be optimal.

(25)

/ x y /			INTEGRITY	UNIFORMITY
a.	Input	x y   /	*	*
b.	Input	x y  X	**	**
c.	Input	x y 		
☞	Output	x y		

Thus, complementary violations of MAX and DEP or of INTEGRITY and UNIFORMITY may be sifted out, reducing the breaches of totality and surjectivity, and functionality and injectivity.

In the cases just reviewed, the choice is between violating Faithfulness and not violating Faithfulness. Minimising violations is relatively straightforward. When it comes to IDENTITY and LINEARITY constraints, two correspondences have a chance of being optimal depending on how constraints are ranked. To fully understand the nature of veritable mapping, we shall now be occupied with examining various alternative formal mappings. Consider, for example, mapping from  $xy$  to  $yx$ . This might be viewed as reordering, resulting in a LINEARITY violation, or as the loss of one item and appearance of an identical one at a different site, resulting in MAX and DEP

violations. Either analysis is possible for the  $xy \rightarrow yx$  mapping depending on the ranking of the constraints, as shown in tableaux (26) and (27). (Since the ranking of MAX and DEP is not crucial we assume  $\text{MAX} \gg \text{DEP}$  without loss of generality.)

(26)

	/ x y /	MAX	DEP	LIN
a.	Input x y / Output y x	*!	*	
b.	Input x y X Output y x			*

(27)

	/ x y /	LIN	MAX	DEP
a.	Input x y / Output y x		*	*
b.	Input x y X Output y x	*!		

A conflict arises between the properties of order preservation on the one hand, and totality and surjectivity on the other, since not all can hold at once in these circumstances. depending a conflict arises since a violation of either may be alleviated by twin MAX and DEP violations, depending on how they are ranked. Similarly with a map  $-F \rightarrow +F$ : the identity property conflicts with totality and surjectivity:  $\text{MAX}_F, \text{DEP}_F \gg \text{IDENT}_F$  leads to optimal  $-F_i \rightarrow +F_i$  with an IDENT violation;  $\text{IDENT}_F \gg \text{MAX}_F, \text{DEP}_F$  leads to optimal  $-F_i \rightarrow +F_j$  with twin violations

of MAX and DEP. So either formal conception of neutralisation of feature values is possible: a value switch, or omission and replacement of the underlying feature.

Nevertheless, in these cases, one of the two correspondences is still recognisable as the veritable one. Conservation of material while merely changing the order (LINEARITY violation) or value (IDENT violation) is simpler because there is just one disparity breaching just one property, whereas the other alternative (MAX violation and DEP violation) has two disparities breaching two properties.

The veritable correspondence may be assured by a stronger appeal to the tenet of minimal constraint violation, drawing on an insight due to Pulleyblank and Turkel (1997). Just as *within an individual grammar* minimal constraint violation determines the relative harmony of candidates, it also evaluates *between grammars*, since constraint violations incurred by a candidate may be less serious in one grammar than in another. Pulleyblank and Turkel (1997) explore the consequences of this for the learnability of constraint hierarchies. Here, if we apply this approach to Faithfulness constraints specifically, we can derive verity of correspondence.

Violations of MAX, DEP, and LINEARITY are more serious in some grammars than others, depending on the ranking. In (28) we look at the candidates from tableaux (26) and (27) over three grammars. Candidate a., which violates MAX and DEP, is most harmonic in the grammar where these are ranked lowest - that is, LIN>>MAX>>DEP. Candidate b., which violates LIN, is most harmonic in the grammar where LIN is ranked the lowest, MAX>>DEP>>LIN. The minimal possible violation is provided in the grammar MAX>>DEP>>LIN where candidate b. has a single violation of the lowest ranked constraint (LIN). Both the grammar and the candidate are awarded the pointing finger to identify this case. Every other case has violations of the first- or second-ranked constraints. Cells are shaded where candidates are ruled out not only in their own grammar, but across the grammars.

(28)

	LIN	MAX	DEP
a. $y_jx$		*	*
b. $y_jx_i$	*!		
	MAX	LIN	DEP
a. $y_jx$	*!		*
b. $y_jx_i$		*	
	MAX	DEP	LIN
a. $y_jx$	*!	*	
b. $y_jx_i$			*

There is potentially a problem of bootstrapping here, if we select the veritable correspondence of candidate b. by using candidate b. to select the grammar  $MAX \gg DEP \gg LIN$ . To avoid bootstrapping, we must begin from a position of agnosticism about the correspondence relation for the input-output pair  $\langle xy, yx \rangle$ . All possible correspondences between the pair provide possible candidates; we want the candidate violating constraints as minimally as possible by selecting the grammar in which the violated constraints are ranked as low as possible. By adopting this approach, the veritable correspondence emerges.

There is a further consequence concerning which correspondence emerges from applying minimality across grammars. Input-output correspondences with one, two, three, or any number of violations of LINEARITY will always be more harmonic than twin violations of MAX and DEP. Here, the use of ranking to demote violated constraints means that *a greater number of constraints violated implies a mapping is suboptimal even if the total number of violations is the same or less than another alternative*. This is illustrated this in tableaux (29-31):

(29)

	/ x y z /	MAX	DEP	LIN
a.	$\begin{array}{c} x y z \\ \parallel \\ z x y \end{array}$	*!	*	
b.	$\begin{array}{c} x y z \\ \diagup \diagdown \\ \text{☞} z x y \end{array}$			**

(30)

	/ w x y z /	MAX	DEP	LIN
a.	$\begin{array}{c} w x y z \\ \parallel \parallel \\ z w x y \end{array}$	*!	*	
b.	$\begin{array}{c} w x y z \\ \diagup \diagdown \diagup \diagdown \\ \text{☞} z w x y \end{array}$			***

(31)

	/ x y z /	MAX	DEP	LIN
a.	$\begin{array}{c} x y z \\   \\ z y x \end{array}$	*!*	**	
b.	$\begin{array}{c} x y z \\ \diagdown \diagup \\ z y x \end{array}$	*!	*	*
c.	$\begin{array}{c} x y z \\ \times \\ \text{☞} z y x \end{array}$			***

This notion of verity says that two strings that draw on an identical set of letters are more naturally said to be related by reordering than by omission and replacement, an intuitively acceptable result.

This covers the various possible interactions between the Faithfulness constraints. At this point, we have clarified the notion of veritable correspondence so that it conforms to the following definition:

(32) **Definition: Verity of Correspondence**

An underlying-surface correspondence is **veritable** if it breaches the smallest possible number of the natural properties of relations.

The natural properties of relations were given in (1), and the Faithfulness constraints correspond to these properties. Minimality of constraint violation ensures that as few Faithfulness constraints as possible will incur violations, and, *at least up to this point*, this leads to veritable correspondences as defined in (32). We test this one step further in the next section.

### 3.3.3 Insertion, Deletion, and Relocation

The relative naturalness of reordering or insertion/deletion has bearing on the analysis of patterns in which items delete and insert in complementary contexts, such as the *r*-zero alternation word-finally in Eastern Massachusetts English (McCarthy 1991, 1993, 1999c, Halle and Idsardi 1997) and some other dialects. Consider an utterance (36) in which *r* is lost from some positions and gained in others:<sup>36</sup>

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<sup>36</sup> We employ the naïve assumption, purely for the sake of argument, that words are underlyingly *r*-less or *r*-final in accordance with how they are rendered orthographically. In fact, “there is often little basis for maintaining the etymological distinction... certainly language learners receive no evidence from which they could infer different underlying representations for *tuna* and *tuner*... More importantly, the facts about the **distribution** of *r* are robust



*sausages*), but evidence from the core of natural language is lacking. Let us then consider whether minimality of constraint violation would force a relocation analysis.

Ranking arguments from minimality of constraint violation initially appear to require relocation in such a case. LINEARITY would need to be ranked low enough to prompt reordering under the right conditions. LINEARITY is not ranked below MAX, for if it were, relocation would be the strategy of choice for *all* unacceptable *rs*, leading to pronunciations like \*[hɔʊmɪə] for *Homer* and \*[jəɪɔ] for *your*. Instead, we require that omission is the strategy of choice, and relocation a secondary strategy when there is a place for the *r* to go. This would follow from the ranking DEP >> LIN >> MAX (“do not insert unless relocation is impossible; relocate if omission would lead to insertion being necessary; omit unless relocation is possible”). DEP >> LIN >> MAX can be selected over LIN >> DEP >> MAX on grounds of less serious violations as in (36).

(36)

/ x y z /			
	LIN	DEP	MAX
a.    x y z    z x y		*	*
b.    x y z // z x y	*!		
☞	DEP	LIN	MAX
a.    x y z    z x y	*!		*
b.    x y z // ☞    z x y		*	

This is the situation with regard to alternative interpretations of a *given* input-output mapping. However, when we look at the system *as a whole*, there is a counter-argument against DEP >> LIN >> MAX. In forms where objects are inserted, the top-ranked constraint (DEP) is violated. Under the rival ranking LIN >> DEP >> MAX, which does everything by deletion and insertion and never allows reordering, the top-ranked constraint (LIN) is never violated, even though the second and third constraints down are sometimes violated together (as in candidate a. in (36)). There is a difference between the two arguments. Even though the outputs are the same and not in dispute, the ranking argument for DEP >> LIN >> MAX in (36) is based on a *conflict* between two alternative candidate analyses (the correspondence relation is part of the candidate – as shown in 2.3), whereas the counter-argument is based on applying the metric systematically so that all constraints that are violated at all in the language are ranked as low as technically possible. So whether or not verity of correspondence holds absolutely turns on whether we rank only to select between alternative correspondences in a given *case*, or as a general strategy of minimising violations or seriousness of violations in a given *grammar*. The more principled choice is the general one - in which case relocation *is* excluded and verity fails in general. This would save us from the possible difficulties in processing utterances in which relocation could occur over any distance, e.g. from one end of an utterance to another, and is consistent with the absence of relocation from normal language.

We have now demonstrated that in Optimality Theory, Verity of Correspondence derives from ranking arguments that decide between alternative analyses of the correspondence mapping on the basis of minimality of constraint violation. However, we have also demonstrated that the full application of this metric - ‘rank-all-violated-constraints-low’ - deviates from the verity property in the case of relocation over an arbitrary distance. In the process, we have shown that the central principle of minimal violation in Optimality Theory determines not only grammatical

surface forms, lexical forms by Lexicon Optimisation (Prince and Smolensky 1993), and constraint rankings (Pulleyblank and Turkel 1997), but also correspondence relations. We now turn to the derivational framework.

### 3.3.4 *Economy of Derivation*

Our goal is to consider how disparities may be minimised order to guarantee natural correspondences between underlying and surface structures. In the derivational framework, the minimisation of disparities is achieved by the minimisation of rule operations. Generation systems in general offer any combination of operations in series and thus inevitably raise the prospect of unnatural derivational history relations that exceed Verity as well as Representativity. The canonical (but not the only) examples of this are the Duke of York gambits. For example:

(37) Insertion-Deletion     $\emptyset \rightarrow x \rightarrow \emptyset$     exceeds Representativity

Deletion-Insertion     $x_i \rightarrow \emptyset \rightarrow x_j$     exceeds Verity

Although insertion-deletion exceeds one property and deletion-insertion the other, they may both be excluded by the single requirement that derivations contain only the minimum of operations. The criterion of minimal derivation length has previously been used to select in syntax between two derivations with equivalent results (Chomsky 1995), to constrain the form of phonological rules (Calabrese 1995), and to limit the abstractness of underlying phonological forms (Kiparsky 1982).

A strict economy of derivation condition, slightly modified, will have as its consequence both the Representativity and the Verity of underlying-surface correspondences. Taking the question of verity first, the minimisation of operations will provide for the minimisation of disparities in the mapping between underlying and surface structures.

A surface form that is identical to the underlying form will be required to eschew deletion and insertion, fission and fusion, double order change, and double value change, which all exceed verity, since the most economical derivation contains precisely no operations. Where a grammar contains two rules that are capable of reversing each other, the condition of economy will select rules that have sufficient restrictions on their application as to prevent creating a long derivation, as Calabrese (1995:447) has observed.

The derivation  $xy \rightarrow yx$  will be done by the single operation of order change, avoiding longer possibilities such as deletion and insertion at different sites:  $xy_i \rightarrow y_i \rightarrow y_i x$ .

Multiple order changes become uneconomical where three or more are necessary, given the alternative of deletion and insertion at the different sites (38a,.b.). General "movement" operations would perform relocation in one fell swoop providing a yet more economical derivation (38c.), although a movement operation describes behaviour only seen in language games, so is presumably unavailable in normal language phonology.<sup>37</sup>

(38)	a.	b.	c.
	wxyz <sub>i</sub>	wxyz <sub>i</sub>	wxyz <sub>i</sub>
	wxz <sub>i</sub> y Order change	wxy Deletion	z <sub>i</sub> wxy Movement
	wz <sub>i</sub> xy Order change	z <sub>j</sub> wxy Insertion	
	z <sub>i</sub> wxy Order change		

<sup>37</sup> Non-adjacent metathesis  $xyz \rightarrow zyx$  is also considerably less cumbersome when it is assumed that general movement operations are available in language play, but deletion-insertion may be worse than multiple order change:

xyz		xyz		x <sub>i</sub> yZ <sub>j</sub>	
xzy	Order change	xy	Deletion	z <sub>j</sub> yX <sub>i</sub>	Movement
zxy	Order change	xyx	Insertion		
zyx	Order change	yx	Deletion		
		zyx	Insertion		

In the previous section, we claimed that these mappings make best sense as a re-ordering of the same segments – i.e. non-order-preserving. Economy of Derivation (39a.) fails to select the veritable correspondence in this instance because it minimises operations rather than types of operations (Deletion, Insertion, Fusion, Fissure, Value Change, Order Change). However, if operations were minimised by type (39b.), the multiple order changes would be selected, since only one type of operation is involved, keeping the verity of derivational mappings.

(39)

**a. Strict Economy of Derivation (standard)**

Adopt the grammar which produces derivations containing the fewest operations.

**b. Strict Economy of Derivation by Type of Operation**

Adopt the grammar which produces derivations containing the fewest types of operations, and then the fewest operations of each type.

Economy of Derivation by Type of Operation would favour relocation by a rule that applies precisely when one *r* is needing to be removed while an *r* is needed at another site, as in (34) and (35), since relocation reduces the types of operation used in the derivation from two (insertion and deletion) to one (change in order). This keeps verity but complicates the rule system with a conspiratorial metathesis rule. Standard Economy of Derivation, on the other hand, would not allow the unlimited order changes necessary to relocate *rs* to new intrusive contexts, since two operations, a deletion and an insertion, are sufficient. Of course, standard Economy of Derivation fails to respect verity in cases of multiple reordering generally, so relocation over an arbitrary distance is merely a specific case. Nevertheless, standard Economy of Derivation succeeds in avoiding the addition of an extra metathesis rule when insertion and deletion rules

already produce the correct results, and it also avoids the potential high processing complexity of relocating segments to different parts of the utterance.

### 3.3.5 Economy and Representativity

We have shown how Verity is secured by Economy of Derivation by Type of Operation. We now show that Economy of Derivation by Type of Operation also ensures *Representativity of Correspondence* – which was defined and discussed in 3.2.5.

The nonrepresentative Duke of York gambits such as insertion-deletion  $\emptyset \rightarrow x \rightarrow \emptyset$  leave no trace whatsoever in the underlying-surface correspondence. Economy of Derivation (either formulation) excludes them. Then there are pairs of operations whose overall effect may be replaced by just one operation. Thus, the result of inserting a feature,  $\emptyset \rightarrow -F$ , and then changing its value,  $-F \rightarrow +F$ , may be obtained by just one operation,  $\emptyset \rightarrow +F$ . Further checking shows that most other nonrepresentative combinations may similarly be replaced by one simple operation, but two cases remain: the first is where a fused element is subsequently deleted (40a), and the second is where an inserted element is made the subject of a fissure (40b).

(40)	a.	stepwise		overall
	1	a b		a b
		∨		
	2	c	Fusion	
	3	∅	Deletion	∅
	b.	stepwise		overall
	1	∅		∅
	2	a	Insertion	
		∧		
	3	b c	Fissure	b c

As is clear from (40a), the representative alternative to fusion-and-deletion is the deletion of both adjacent objects in the original structure. But this alternative also consists of two operations, no more economical than before. Similarly for (40b), the alternative to the Trojan Horse strategy of insertion of an object followed by breaking it into two is merely the insertion of two objects. Again, this still uses two operations, again no more economical. Only when we appeal to Economy of Derivation by Type of Operation can we discriminate against these in favour of the representative alternatives. Then deletion only is selected over fusion and deletion, and insertion only is selected over insertion and fission.

Now, these scenarios are clearly unusual: (40a) represents a case where two objects are deleted in a given context, while (40b) represents a case where two inserted objects appear in a given context. For example, Wheeler and Touretzky (1993:170) note that a pair of insertion rules  $\emptyset \rightarrow a$ ,  $\emptyset \rightarrow b$  in the same context  $p\_q$  are unattested in any one language – suggesting a fortuitous limit on computational complexity in language, which apparently need not contend with the problem of determining the relative linear order in which the objects  $a, b$  are to appear. Nevertheless, some objects may be inserted adjacently. Stem augmentation in Lardil nominatives, for example, employs some consonant-vowel sequences, e.g. *kanta* vs. nonfuture accusative *kan-in*. Strict Economy of Derivation by Type of Operation requires in any such case that objects are inserted or deleted without the use of fusion or fission. It seems unlikely that one would find empirical grounds for an insertion-and-fission Trojan Horse gambit in a language (vowel epenthesis followed by diphthongisation of the vowel, for example, goes against the expectation that epenthetic vowels take the unmarked, default quality), but it is a formal possibility given the standard Economy of Derivation principle.

We have now seen how Strict Economy of Derivation by Type of Operation (35b) provides for both Representativity and Verity. So with one single condition, derivations may be

confined to those whose mapping observes two complementary simple properties: excluding the introduction both of disparities that would *not* be reflected in underlying-surface correspondences, and of disparities that *could* be reflected there but would offer greater complexity than necessary.

### 3.3.6 Summary: Minimality of Violation & Economy of Derivation

Having identified two simple properties – representativity and verity – that might be applied to correspondence mappings between underlying and surface structures, we have found that these are achieved in the two frameworks if the familiar strategies of economy of derivation and minimality of constraint violation are modified slightly from their simplest form.

This is possible because the strategies of economy of derivation and minimality of Faithfulness violations have essentially the same form: as few Faithfulness constraints as possible are violated, as few times as possible, or, as few types of operations as possible are used, as few times as possible. The similar effects obtained by this common strategy of *minimisation* serve to further substantiate the basic analogy between operations and Faithfulness violations on which the formal comparison is built. The similar results are summarised in (41) below.

#### (41) Results

<i>Derivational Framework:</i>	<b>Verity</b>	<b>Representativity</b>
strict Economy of Derivation <i>by type of operation</i>	✓	✓
strict Economy of Derivation <i>standard version</i>	✗ Disfavours reordering more than twice	✗ Admits Trojan Horse derivations

<b><i>Optimality Framework:</i></b>	<b>Verity</b>	<b>Representativity</b>
Minimal Violation metric <i>applied in case of conflict</i>	✓	✓ (vacuously)
Minimal Violation metric <i>applied over language as a whole</i>	✗ Disfavours reordering over an arbitrary distance	✓ (vacuously)

We have shown in detail how Optimality Theory and Minimalist derivational theory make very similar predictions as to the complexity of the underlying-surface correspondence. However, they can be distinguished as to their explanatory value. Minimality of constraint violation lies at the very heart of Optimality Theory, being the very basis of optimisation, but in derivational theory, the Economy of Derivation principle must be specially added. Furthermore, in Optimality Theory, minimality of constraint violation determines four interlocking aspects of the phonological grammar – surface forms, underlying forms, constraint rankings, and underlying-surface correspondences. In derivational theory, however, the economy of derivation principle determines just two of these - underlying-surface correspondences (which we have demonstrated) and choice of underlying form (as discussed by Kiparsky 1982). If naturalness of correspondence can be sustained empirically – and in the next section we claim that it can – then it is Optimality Theory that offers greater explanatory depth here, since it explains the particular predictive properties of the special principle of Economy of Derivation within a more general scope.

### 3.4 The Duke of York Gambit

Having compared how the underlying-surface mapping is handled in the two theoretical frameworks, it remains to examine the viability of maintaining a natural correspondence between underlying and surface structures. In particular, if the “Duke of York gambit” proved to be necessary in phonology, as Pullum (1976) claimed, it would undermine both Optimality Theory and Minimalist derivational theory. We claim here that the unnaturalness of the Duke of York mapping not only explains phonologists' negative reactions to it, but also shows it to be unexplanatory. We then show that its exclusion is supported by the empirical evidence after all.

#### 3.4.1 *The Trouble With The Duke of York Gambit*

Natural correspondences are often assumed implicitly in the literature with little or no discussion. In Optimality Theory, McCarthy and Prince (1995) pointed out that all manner of correspondence relations are possible for any given output, but in practice, only one intuitively obvious correspondence relation (the natural one) for a given output is at all interesting. Optimality theorists want to explain why this output is optimal and not that one; the question of why it is this correspondence relation and not that one is merely a matter of technical hygiene whose outcome is nearly always intuitively obvious. Similarly, rule analysts may well assume that the operations that apply are those which are evident in the resulting forms. Concerning rules of Lengthening and Shortening of stressed vowels in English, Halle (1995:27,28) observes that

"On the one hand, in words such as *divin-ity*, *natur-al* and *ton-ic*, *athlet-ic*, as well as in *Palestin-ian* the stem vowel is shortened, but there is no shortening in *ton-al* or *atone-ment*. On the other hand, there is lengthening in *Caucas-ian*, *remedi-al*, but not in *remedy-ing*, *burial* or *Casp-ian*."

"strings having the same form as the output of the more restrictive <Lengthening> rule are prohibited from undergoing the less restrictive <Shortening> rule... as a consequence, neither *Shakespear-ian* nor *jov-ial* are subject to Shortening".

Shortening applies to the head vowel of a branching foot, while Lengthening applies to the head vowel of a branching foot **provided** the vowel is [-high], the following vowel is /i/, and the vowel following that is in hiatus with /i/. What is most interesting is what happens when both rules could potentially be relevant in the same derivation. Halle's explanation as to why the head vowels in words such as *Shakespearian* and *jovial* are long is that Shortening is blocked. If this is so, then the rules apply only when it is clear from the surface forms that they have. In fact, as Prince (1997b) points out, it would be unnecessary to prevent Shortening from applying to *Shakespear-ian* and *jov-ial* since in these cases Shortening would be followed by Lengthening, still giving the correct result. The two options are shown in (42), where length is indicated by moras ( $\mu$  - short,  $\mu\mu$  -long):

(42)	$jo_{\mu\mu}vial$	or	$jo_{\mu\mu}vial$	
	<i>blocked</i>		$jo_{\mu}vial$	Shortening
			$jo_{\mu\mu}vial$	Lengthening
	[dʒouviəl]		[dʒouviəl]	

The second alternative would explain why the surface vowel is long without the need for an extra constraint on the application of Shortening. Only if it is implicitly assumed that underlying-surface correspondences are natural is it necessary to explain the long surface vowels by the nonapplication of Shortening.

An intuitive respect for the naturalness of the underlying-surface mapping by phonologists explains their long-standing though somewhat inchoate suspicion of the Duke of York gambit. Pullum (1976:84-85) cites a number of authors' comments on such analyses: "suspicious", "juggling", "complicate the description", "illegitimate practice", "unattractive",

“farcical”, “missing something”. More recent authors continue the trend, calling the strategy “dubious” (McCarthy 1993a:182), an “implausible expedient” (McCarthy 1993b:7) and “undesirable” (Halle and Idsardi 1997:346). When Iverson (1989) offers an analysis of alternations of laterals in Klamath in terms of gemination and degemination, an apology is deemed necessary for the two-part creation and dissolution of a geminate in derivations /l̥/ → l̥: → [lh], /l̥/ → l̥: → [lʔ], though that apology is no more than the offer of a mirage lacking in any factual support:

"independence of its parts *might* lie in stylistic variation between the geminated, presumably careful speech product of [the first process] and reduced, possibly more casual output of [the second process], *although Barker (1964) himself gives no evidence of the distinction*" (Iverson 1989:297 *my italics*).

It is not the mutually-contrary *rules themselves* that are seen as risible: rather, even when an analyst is content to defend two contrary rules in a description, it is their occurrence in the same *derivation* that is considered curious. Thus, McCarthy (1991) demonstrates that both insertion and deletion operations are necessary in the analysis of stem-final *r* in Eastern Massachusetts English, but he rejects the possibility of one altering the outcome of the other in a derivation:

This analysis may be a descriptive success, but it is an explanatory failure. The derivations are dubious, because many *r*'s are inserted at Word level only to be deleted phrasally in what Pullum 1976 calls the "Duke of York gambit". (McCarthy 1993a:182)

It is not made clear what such derivations supposedly fail to explain, but the author seems to imply that objects that have to be deleted should not have been inserted in the first place. The reference to Pullum does not help because his position was that “the Duke of York gambit will be reasonable precisely when the result is a reasonable analysis, and unreasonable precisely when

it is not” (Pullum 1976:100). Nevertheless, Halle and Idsardi (1997:343ff) do precisely the same as McCarthy, arguing that *r*-insertion and *r*-deletion rules are both necessary for Eastern Massachusetts English, yet still insisting that the analysis must specifically avoid the two applying in the same derivation, even though the correct results can still be obtained that way.

These negative reactions to the Duke of York gambit, that have been persistent over the history of Generative Phonology despite the descriptive correctness of the analyses, may collectively be explained as the intuitive rejection of derivations that bring about a relationship between underlying and surface structures which is not the natural one.

#### 3.4.2 *The Duke of York Gambit as Unexplanatory*

The Duke of York gambit fails to explain why the surface form is so similar to the underlying form – and, therefore, to the other alternants on the basis of which the underlying form is set up. On the Duke-of-York analysis, they are similar by accident, because a rule happens to re-create the same configuration as was there to start with. The similarity of the surface form to its underlying form is only *explained* by a grammar that *preserves the configuration as it is*.<sup>38</sup> Duke of York derivations create a derivational history which exceeds the naturalness that is necessary to explain similarities in form between alternants; properly economical derivations explain similarities in alternants. Indeed, the empirical record shows that formal naturalness of the underlying/surface relation is preserved, so that phonology explains both why forms are as they are and why they are similar to their alternants. Other uneconomical derivations are unexplanatory. Metathesis  $x_1y_2 \rightarrow y_2x_1$  is superior to uneconomical deletion and re-insertion at the new site because deletion and re-insertion fail to explain why the string has

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<sup>38</sup>The similarity between the forms may be explained historically, if one of the rules in the Duke of York analysis arose as a hypercorrection of the other rule: Halle and Idsardi (1997) claim that Eastern Massachusetts English *r*-insertion arose as a hypercorrective rule, though they still prefer to block the Duke of York derivation in the synchronic grammar of current Eastern Massachusetts English.

identical elements, if in a different order. The unnatural relocation *over an arbitrarily large distance*,  $x_i \dots \emptyset \rightarrow \emptyset \dots x_i$  (see 3.3.3), however, would be an over-ambitious attempt to "explain" the identity of objects that are being systematically added and removed from unconnected sites, whereas the derivationally economical analysis using only insertions and deletions is also a more straightforward description of effects at unrelated sites.

This account of the explanatory inadequacy of the Duke of York gambit locates it in a broader issue affecting unnatural underlying/surface relationships, and replaces previous, unviable criticisms of the Duke of York gambit, such as the objection of Halle and Idsardi (1997:344):

*r*-deletion preceding *r*-insertion results in derivations where the effects of *r*-deletion are repaired by *r*-insertion. This type of interaction has been termed by Pullum 'the Duke of York gambit' and objections to it have been raised on the grounds that the gambit subverts the essential difference between rules, which reflect idiosyncratic facts of a language, and repairs, which are consequences of general structural principles obeyed by the language.

Objecting that the gambit subverts the difference between rules and repairs assumes that the second rule is somehow 'acting as' a repair. This is merely in the eye of the beholder. Repairs are context-free rules that change structural configurations; they are unordered and apply persistently (Myers 1991). In the analysis discussed here, *r*-insertion is clearly not a repair rule but an idiosyncratic, ordered rule (Halle and Idsardi 1997:343-4). The *r*-deletion rule removes *r* from codas, and the *r*-insertion rule is subject to an array of conditions that would not be placed on a repair: a hiatus-filler in coda (rather than onset) position; only following non-high vowels; and only in derived environments (or rather at Prosodic Word boundaries - McCarthy 1999c:8-9). The choice of *r* as the inserted segmental structure is a particular and complex phonological stipulation (McCarthy 1993a, Blevins 1997), not a simple structural adjustment that would be characteristic of a repair. It is simply incorrect to say that *r*-insertion **repairs** the overapplication of *r*-deletion: it just **reverses** it. It is indicative of the very broad, formal nature of the Duke of

York gambit that a rule may conceivably be reversed by an unordered, persistent, repair rule or by a subsequently-ordered idiosyncratic rule.<sup>39</sup>

What the Pullum (1976) study showed was that the Duke of York gambit is “an independent issue, cutting across many other issues in phonological description” (Pullum 1976:94). It is independent of opacity, abstractness, and stipulative rule ordering (Pullum 1976:89-94), but also independent of the ordered rule / repair rule distinction. It has to do with constructing an underlying-surface correspondence, and is not the most simple way of doing so.

### 3.4.3 Eastern Massachusetts *r*

It is true that some Duke-of-York derivations have arisen in eccentric analyses which are disputable on independent grounds (Pullum 1976:88). But even the case of Eastern Massachusetts English *r*, which is amenable to a Duke of York analysis at least for the most familiar data in (43), does not go through when additional data is considered. The basic pattern of *r*~∅ alternation is as follows:

(43)

- |                       |                                    |                                     |
|-----------------------|------------------------------------|-------------------------------------|
| a. Before a vowel     | <i>I put the tuna on the table</i> | <i>I put the tuner on the table</i> |
|                       | [...tjunəɹ ɒn...]                  | [...tjunəɹ ɒn...]                   |
| b. Not before a cons. | <i>I put the tuna down</i>         | <i>I put the tuner down</i>         |
|                       | [...tjunə daʊn]                    | [...tjunə daʊn]                     |

<sup>39</sup>If one repair A→B was accompanied by another B→A (a curious theoretical possibility noted by Scobbie 1991:18), then each would repeatedly reverse the other in a derivation that fails to terminate. Repetition is disallowed by a universal constraint banning reapplication of either unordered rule in interrupted sequence (Ringgen 1976). However, according to Myers (1991), repairs apply “persistently”, in direct contradiction to Ringgen, in which case mutually-reversing repairs *would* fail to terminate.



## (44) Procliticised Function Words (McCarthy 1999c)

<b>r Not Inserted:</b>	<b>r Present:</b>
<i>to Ed</i>	<i>for Ed</i>
[tə ɛd]	[fəɹ ɛd]
<i>to add to his troubles</i>	<i>for any reason</i>
[tə æd tə ɪz tɹɒbəlz]	[fəɹ ɛni ɹɪzən]
<i>why do Albert and you</i>	<i>they're eating</i>
[waɪ də ælbət ən juw]	[ðeəɹ ɪjɹɪŋ]

Insertion must be restricted so as not to apply to words on the left, by restricting it to apply at the right boundary of a phonological word and not at a proclitic-word juncture (McCarthy 1999c:9). But then the words on the right would be subject to coda *r*-deletion in a context where insertion does not restore the *r*, wrongly leaving them *r*-less. Coda *r*-deletion must therefore be restricted so as not to apply to the coda *rs* on the right. One possibility might be that *r*-deletion, like *r*-insertion, applies only at the right boundary of a phonological word - but this misses the fact that the absence of coda *r* is very general except for a few special positions (word-finally and proclitic-finally). A more satisfactory alternative is to re-formulate the generalisation so that *r* is deleted from *all strict* codas - not from prevocalic codas, which are *ambisyllabic* (Kahn 1976) and therefore the *r* is licensed by its onset affiliation even though it inherits the phonetic quality of the coda. And *this* precludes a Duke-of-York interaction between *r*-deletion and *r*-insertion, since it means that prevocalic *r* in "*Homer is difficult*" will not now be deleted and in need of re-insertion.

### 3.4.4 Evidence Against *The Duke of York Gambit*

Pullum (1976:100) was led to conclude that Duke of York derivations are an inevitable and integral component of the description of at least a residue of cases of mutually contrary processes in a derivational system, and CANNOT justifiably be disallowed (see also Zwicky 1974, Prince 1997b). This lines up with the dictum of Kiparsky (1982:172): "derivational simplicity is strictly subordinated to grammatical simplicity, and only comes into play when the evaluation measure is indeterminate as between alternative grammars." On this view, preference for shorter derivations would be relative, not absolute. In fact, the evidence - hitherto unrecognised - goes against Pullum's conclusion. Consider a language with both epenthesis and syncope of vowels. Their combined application in derivations would be detectable because the whole vowel inventory would collapse in that context down to the epenthetic vowel quality:

$$(45) \quad \{i, e, a, o, u\} \rightarrow \emptyset \rightarrow \{i\}$$

Alternatively, failure of combined application would leave the vowel inventory intact. Not all syncope languages are testing grounds for inventory collapse vs. preservation: there may be one vowel which undergoes both syncope and epenthesis (e.g. /i/ in Palestinian Arabic, Brame 1974), in other languages, vowels of any quality may undergo syncope but there is no epenthesis reported (Maltese, Brame 1974; Southeastern Tepehuan, Kager 1997). But general vowel syncope and *i*-epenthesis come together in Yokuts (Kuroda 1967, Kisseberth 1970a). In Yokuts, collapsing of the vowel inventory does not occur; rather, the two processes occur precisely in *complementary* contexts as in (46):

(46) **Epenthesis:** CC\_C or C\_C]

xat-t	[xatit]	‘ate’
paʔɬ-hin	[paʔiɬhin]	‘fight’-aorist

**Syncope:** VC\_\_CV

kili:y-a-ni	[kileyni]	‘cloud’-indirect objective
xat-a-ni	[xata:ni ~ xatni]	‘eating(N)’-indirect objective
(cf. polm-a-ni	[polma:ni]	‘husband’-indirect objective)
hall-(h)atin-i:n	[hallatnen]	‘lift up’-desiderative-future
(cf. bint-(h)atin-xu:-k’a	[bintatinxok’]	‘be trying to ask’) <sup>40</sup>

Cross-linguistically, syncope consistently fails to apply just when it would create consonant clusters that do not fit the syllable structure of a language (Myers 1991:318), while vowel epenthesis is repeatedly employed to break up consonant clusters that do not fit the syllable structure. So syncope and epenthesis occur in disjoint contexts systematically. It is also the case that “it is not unusual to find processes of vowel deletion creating complex clusters that are broken up by epenthesis in a different place, such as /yiktibu/→*yiktbu*→*yikitbu* in some dialects of Arabic.” (McCarthy 2002:169-170). An Amerindian language, Chukchee, displays vowel syncope and epenthesis at different sites in this way:

<sup>40</sup>The complementary nature of syncope and epenthesis means that instances of /i/ may either be analysed as syncopated in the contexts where they do not appear, or epenthised in the contexts where they do appear. Thus Archangeli (1985:347) analyses the desiderative suffix as /atn/, with epenthesis possible between the /t/ and /n/. However, this will not work for instances of syncopated /a/, demonstrating that a syncope process is operative in Yokuts in addition to an epenthesis process.

(47) (Kenstowicz 1994:106)

	abs.pl.	erg.	abs.sg.
‘load’	imti-t	imti-te	imət (imti→imt→imət)
‘box’	cenle-t	cenle-te	cenəl (cenle→cenl→cenəl)
‘walrus fat’	lonla-t	lonla-te	lonəl (lonla→lonl→lonəl)

By contrast, Duke of York interactions between syncope and epenthesis applying at the *same* site are to my knowledge unattested.

In another example, loss of the final stem vowel is used morphologically to mark the nominative for Lardil nominals (Prince and Smolensky 1993:97ff, Hale 1973), yet short words are phonologically augmented by word-final epenthesis. Again, although a Duke-of-York derivation would be possible in certain words, it does not in fact occur. In (48a), apocope-marked nominatives are shown, where vowel absence is denoted by "\_"; in (48b), monomoraic stems (those containing just one short vowel) are shown augmented in the nominative by an epenthetic **a** vowel; in (48c), bimoraic stems (containing precisely two short vowels), which might have been susceptible to both subtraction and augmentation, in fact exhibit neither.

(48)	Nominative	Nonfuture	Future	Gloss
		Accusative	Accusative	
<b>a. 3+ Vowels: Subtraction</b>				
/yiliyili/	yiliyil_	yiliyilin	yilyiliwuṛ	'oyster sp'
/mayaṛa/	mayaṛ_	mayaṛan	mayaṛaṛ	'rainbow'
<b>b. 1 vowel: Augmentation</b>				
/yak/	yaka	yakin	yakuṛ	'fish'
/ṛelk/	ṛelka	ṛelkin	ṛelkuṛ	'head'
<b>c. 2 vowels: Neither</b>				
/mela/	mela	melan	melaṛ	'sea'
/wiṭe/	wiṭe	wiṭen	wiṭeṛ	'inside'

A stem like *mela* does not settle the matter, since it may or may not derive by  $a \rightarrow \emptyset \rightarrow a$ .

However, the preservation of the stem *wiṭe* in the nominative shows that there is no  $e \rightarrow \emptyset \rightarrow a$  derivation. Impoverishment of {i,e,u,a} to {a} does not take place in the final vowels of bimoraic nominatives, providing decisive evidence that subtractive nominative marking and word augmentation apply in complementary contexts in Lardil, not at the same site.<sup>41</sup>

The overall pattern is that impoverishment of the vowel inventory in some context down to a single vowel, the epenthetic vowel, is not found; instead, there are cases where vowel

<sup>41</sup> Our proposal for disjunctivity goes against a hypothetical reconstruction by Blevins (1997) of the historical development of truncation in Lardil. As well as final vowel deletion there is a process that lowers final vowels. This predates the vowel deletion process, when it would have applied to all stems, e.g. \*/yalulu/ →\*[yalula], but is now only visible on the bimoraic stems which resist deletion, e.g. /ngawu/ →[ngawa]. Blevins (1997:255) claims that "subsequent to V-lowering..., the final [a] of the stem could be reanalysed as an instance of nominative /-a/, with deletion of preceding stem-final /u/. Subsequently, the paradigm was levelled by loss of all nominative /-a/s, in favour of the  $\emptyset$  form of the case-marker, still occurring in some /i/-final and all /a/-final stems like /mela/ 'sea'." The

deletion and insertion apply in disjoint contexts, and cases where vowels are inserted at a different site to the deletion site. This holds true both for syllable-based patterns of syncope and epenthesis (Yokuts, Chukchee), and for word-based patterns of subtraction and augmentation (Lardil). It remains to be seen whether a case of impoverishment by contrary processes might be brought to light, but on the available evidence we claim that this is not possible.

#### 3.4.5 Resyllabification and Trans-Domain Interactions

Another possible type of evidence for a Duke of York derivation would be where a rule crucially depends on the intermediate stage between two contrary rules and so necessarily intervenes between them. If it necessarily intervenes between them, then clearly they must both apply - before and after the intervening one. McCarthy (2003) has reanalysed some putative examples of this and claimed that such cases are generally lacking, but there remain some special subcases.

For example, a segmental process may be conditioned by a syllable structure which is subsequently erased and replaced. In such examples, the two contrary operations are ones which build and erase constituent structure (e.g. syllable structure). Thus, syllabification rules may feed certain segmental processes dependent on syllable structure, followed by the erasure of that syllable structure. In an example from Attic Greek (Noyer 1997:510), adjacent nuclear vowels are subject to a rule of Contraction which brings them together as one syllable, e.g. *p<sup>h</sup>i.(lé.e).te* → *p<sup>h</sup>i.(lé)te..* The second of the two syllables is built and then destroyed, though its earlier presence was crucial to the analysis in ensuring correct placement of antepenultimate stress opaquely on *.lé.*, not on *.p<sup>h</sup>i.* as expected from the surface form. The special feasibility of resyllabification effects is amenable to explanation using Optimality Theory: see McCarthy

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middle stage of her reconstruction contains precisely the scenario we have excluded - truncation (e.g. /u/-loss) and augmentation (/a/) together.

(2003) for an account using sympathy theory, and chapter 6 for an account in a theory of serial cumulation of constraints.

In addition to this, McCarthy (2003) notes data from Hebrew which shows that Duke of York gambits may occur due to rules with different domains of application. In words that bear the prepositional prefixes /bi#/ 'in' or /ki#/ 'like', postvocalic spirantisation (a process discussed again in 6.2.2) may be crucially conditioned by a vowel that is inserted and subsequently deleted again. Thus, in one stratum, the stem is subject to epenthesis and spirantisation [bi[ktob]] → [bi[kətob]] → [bi[kəθoβ]], operations also used to produce the free-standing word kə.θo:β 'writing'. In a subsequent stratum, other rules including removal of schwa apply to the domain that includes /bi#/ deriving the final form bikəθoβ → bix.θo:β. The sequence of mappings across the two strata contains the ∅→ə, ə→∅ combination so is not representative under serial composition, but within each stratum the mapping is representative. Alternatively, in Optimality Theory, this can be interpreted as a paradigm uniformity effect between the bi# form and the free-standing form (McCarthy 2003). The free-standing form exhibits vowel insertion and postvocalic spirantisation, and the spirant is carried over to the bi# form by paradigm uniformity even in the absence of a conditioning vowel there.

The Duke of York gambit *can* have explanatory value if the intermediate stage is crucially necessary to condition another process. Then the Duke of York gambit would crucially explain why the output attested that process. This applies to the cases attested here. Another uneconomical derivation that can be explanatory is feature insertion followed by value change ∅ → [-F] → [+F], which has explanatory value if the feature actually behaves as [-F] for purposes of some process even though the surface value is [+F]. We shall argue in 6.2.5 that cases of this kind also occur.

### 3.4.6 Summary: A Universal Property

The evidence, not only from the lack of intervening rules (McCarthy 2003), but also from the maintenance of vowel inventories in the face of potential collapse in languages with vowel deletion and vowel insertion, suggests that a disjunctive interaction between contrary processes is a universal property of language – the opposite of Pullum’s conclusion (Pullum 1976:100):

(49) **Universal Interaction of Mutually Contrary Operations**<sup>42</sup>

Mutually contrary operations on segmental structure apply in distinct contexts.

This would explain the phenomenon of the maintenance of vowel inventories as an inevitable part of language, that does not need to be specially learned – learners do not have to find a way to block vowel deletion to avoid collapsing the inventory. It can be derived either from Economy of Derivation or from Minimal Constraint Violation. It could be proved false if any evidence comes to light of prevarication on the part of learners or the adopters of fresh contrary processes, or of a stable impoverishment pattern in any language.

The universality of the interaction is expected to apply to morphological operations, as in Lardil, as well as phonology proper. In Optimality Theory, the formalism appears at first sight to allow for the possibility that (49) fails specifically when it comes to morphological operations. In Lardil there is a conflict between the phonology and the nominative marking which is resolved by satisfying the FOOT-BINARITY constraint "Feet (...) <sub>FT</sub> contain two moras" at the expense of violating the REALISEMORPHEME constraint which requires that morphological categories (here, nominative case) be marked by some deviation from the plain stem (Kurisu 2001). The tableau in (50) illustrates this:

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<sup>42</sup> The notion of ‘mutually contrary’ processes will be given a precise treatment in 4.3.

(50)

/wi <sub>ɿ</sub> e <sub>i</sub> /	FT-BIN	DEP(V)	REALISE MORPHEME	MAX(V)
a. (wi <sub>ɿ</sub> e <sub>i</sub> ) <sub>Ft</sub>			*	
b. (wi <sub>ɿ</sub> ) <sub>Ft</sub>	*!			*
c. (wi <sub>ɿ</sub> a <sub>j</sub> ) <sub>Ft</sub>		*!		*

If DEP(V) were not crucially ranked above REALISEMORPHEME, candidate c. would be optimal. This predicts that the stem-final vowel would be replaced by *a* in bimoraic stems, apparently simulating an uneconomical  $e \rightarrow \emptyset \rightarrow a$  derivational sequence. However, the input/output analysis  $\langle wi_{ɿe_i}, wi_{ɿa_j} \rangle$  is an unnatural correspondence - as Prince and Smolensky (1993:112) intuitively recognise when they call it a "devious analysis". Therefore, it would be ruled out if the Minimal Violation Metric is given full application (see 3.3.2), avoiding twin MAX and DEP violations. Hence, a genuine instance of a morphological deletion that is reversed by phonological insertion would constitute a counterexample to the minimal-violation-metric approach.

### 3.4.7 An Unsuccessful Proposal: The Elsewhere Condition

Halle and Idsardi (1997) claim that Duke of York derivations are precluded by the Elsewhere Condition. Although it is claimed that the Elsewhere Condition (Kiparsky 1973) is “among the most important contributions to phonology” (Halle and Idsardi 1997:344) and “an empirical result of some importance” (Halle 1995:27), no evidence is offered for the impossibility of combined application of any pair of mutually contrary rules with properly nested environments, nor *for* the necessity of combined application of any pair of mutually contrary rules whose environments are *not* properly nested. Both pieces of evidence are required if the

proposal is to be tenable, but as we have seen, such evidence has to be subtle because the two derivational strategies usually provide equally successful descriptions. As pointed out by Prince (1997b), this leaves no apparent reason to augment rule theory with the special condition.

It is true that in the original paper on the Elsewhere Condition, Kiparsky (1973:100ff) claims to show that in Vedic Sanskrit, two rules in a special/general relationship implicating the values [+syllabic] and [-syllabic] on high vowels, are found not to apply in the same derivation. He predicts that the intermediate stages of putative  $w \rightarrow u \rightarrow w / j \rightarrow i \rightarrow j$  derivations would be expected to be retained in certain metrical contexts, and yet are not. Even if Kiparsky is right about Vedic Sanskrit (Howard 1975 disputes this), the result is merely consistent with our general claim that Duke of York interactions do not occur, and does not necessarily support the view that only those in a special/general relationship are blocked.<sup>43</sup> McCarthy (1999c) shows that the Elsewhere Condition cannot account for all the data in the case of Eastern Massachusetts English *r* (Halle and Idsardi 1997).

### 3.5 Conclusion

There is a substantial analogy between operations of rules and violations of Faithfulness constraints that provides a productive area of formal comparison. The correlation is stronger when derivational history relations are representative of their derivational steps, a property which does not hold of all derivations.

The Economy of Derivation Principle of Minimalism, and the Minimal Violation Metric of Optimality Theory, confine grammars to natural correspondences which exclude various

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<sup>43</sup> In fact, of the two rules, one changes [-syllabic] to [+syllabic] and one changes [+syllabic] to [-syllabic], which means that the structures affected by one rule are not nested in those affected by the other rule. They only appear to be in a special/general relationship when they are expressed in an implicational format, with the feature [syllabic] mentioned only in the outcome and not in the structural description of the rule. This format is questionable because, although such rules achieve greater simplicity, implicational rules have to be interpreted differently from the usual transformational rules (see 2.1.2).

intuitively unexpected maps such as deletion and re-insertion at the same site, or relocation of a segment over an arbitrary distance. Optimality Theory offers greater explanatory depth, making similar predictions to those of the special principle of Economy of Derivation within its own more general scope.

The elimination of the unnatural Duke-of-York mappings is correct on empirical grounds, given evidence from patterns of deletion and insertion of vowels. The Duke-of-York proscription includes morphology as well as phonology proper. The proscription also allows us to explain similarities between alternant forms, rather than leaving these similarities as accidental consequences of certain rules. Recalcitrant Duke-of-York gambits are confined to special subcases: the building and erasing of constituent structure leading to ‘resyllabification’ effects, and cases that may be interpreted as paradigm uniformity effects, as in Hebrew (see 5.3 for another type). In chapter six, we will provide a theoretical system whose predictions and limitations prove to coincide with these empirical observations.

**4:****RULE INTERACTION AND CONSTRAINT INTERACTION**

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The basic elements of derivational and optimality grammars are the rules or the constraints, and the pattern of surface representations is derived from the interaction between these basic elements. To govern the interaction of basic elements, the derivational framework employs an ordering relation on rules, and the optimality framework employs an ordering relation (termed a "ranking") on constraints.

Once we draw an analogy between rules and constraints, we may compare systematically the interaction of rules in serial order with the interaction of constraints in rank order. We then find that although certain patterns are derivable either way, each system derives some patterns that are not replicated by the other. We will catalogue these convergences and divergences at length, correcting statements of previous commentators. Since there is empirical support both for patterns derived exclusively by serial rule interaction *and* for patterns derived exclusively by constraint interaction, a fully adequate phonological theory must combine the descriptive capacities of both approaches.

**4.1 The Rule-Constraint Analogy**

In this section we will first establish the foundational point that an analogy exists between rules and constraints. If rules and constraints can be correlated with each other in some way, then it will make sense to compare interactions among rules with interactions among constraints.

The analogy between rules and constraints lies in the fact that both rules and constraints *discriminate* between phonological representations - representations may be marked out as satisfying the structural description of a rule, or equally, marked out as violating a constraint. If

M is a structural configuration contained in some representations, then M may be employed as the structural description of a rule which maps representations containing M to representations which lack M. Or, M may be specified by a Markedness constraint, \*M, which gives violation marks to representations containing M. In (1), we show the correlation between a degemination rule and a no-geminate constraint:

(1) a. *Rule*

X X

\ ≠

[+cons]

b. *Markedness Constraint*

\*X X

\ /

[+cons]

c. *Structural configuration shared by both*

X X

\ /

[+cons]

Indeed, representations might contain M several times over: meeting the structural description of the rule several times over, or violating the constraint several times over. Since rules and constraints both discriminate among representations, they both define mathematical *relations* in the set of representations. In particular, markedness constraints determine that some representations are **less harmonic than** others, by virtue of the fact that they violate the constraint. And a rule determines that, within derivations, some representations are **immediately**

**succeeded by** new representations, by virtue of the fact that they meet the structural description of the rule. This is illustrated in (2) for a degemination rule and no-geminate constraint:

(2)	<i>Degemination Rule:</i>	<i>No-Geminate Constraint:</i>
	atta <b>immediately succeeded by</b> ata	atta <b>less harmonic than</b> ata
	attatta <b>immediately succeeded by</b> atatta	attatta <b>less harmonic than</b> atatta
	atatta <b>immediately succeeded by</b> atata	atatta <b>less harmonic than</b> atata

Since rules and markedness constraints both define relations in the set of representations, the relations may coincide. Immediate succession relations are more restricted than harmony relations, however, because they pick out one particular form as successor, whereas there are many forms that are more harmonic, even minimally more harmonic than a given representation. For example, a degemination rule may delink the first timing unit of the geminate or it may delink the second (1a), but *any* non-geminate structure is better than a geminate when evaluated against a no-geminate constraint (1b). Nevertheless, the relations coincide to the maximum extent if they pick out representations using the same structural configuration *M*, which is the case with the degemination rule and the no-geminate constraint. If a rule and a constraint overlap to the maximum extent, we shall say they are **strongly analogous**. Strong analogy means that all representations which meet the structural description *n* times over also violate the constraint *n* times over, and vice versa. This is expressed in algebraic form in the accompanying text box:

### Strong Analogy

Let  $R$  be a rule and  $C$  an output constraint.  $C$  partitions the set of representations into equivalence classes  $C_0, C_1, C_2, C_3, \dots$  where, for each  $n \geq 1$ , all representations in  $C_n$  are isoharmonic, but all are less harmonic than representations in  $C_{n-1}$  (and hence in  $C_{n-2}, \dots, C_0$ ).  $R$  partitions the set of representations into equivalence classes  $R_0, R_1, R_2, R_3, \dots$  where, for each  $n$ ,  $R$  maps each representation in  $R_n$  to some member of  $R_{n-1}$ .

$R$  and  $C$  are **strongly analogous** if they define identical equivalence classes in the representational set,  $C_1 = R_1, C_2 = R_2, \dots$  and  $C_n = R_n$ , for  $n=1,2,3,\dots$ .

If  $R$  and  $C$  are not strongly analogous, then we can always define a strongly analogous rule and constraint  $R'$  and  $C'$  derivatively, such that  $R'$  and  $C'$  partition the set of representations into equivalence classes containing only those representations that are partitioned off by BOTH  $R$  and  $C$ . Thus,

$$C'_1 = R'_1 =_{\text{def}} C_1 \cap R_1,$$

$$C'_2 = R'_2 =_{\text{def}} C_2 \cap R_2, \dots$$

$$\text{In general, } C'_n = R'_n =_{\text{def}} C_n \cap R_n, \text{ for } n=1,2,3,\dots$$

A lesser correlation than that of strong analogy is conceivable. Compare a general degemination rule to a constraint against *voiced* geminates, or compare a degemination rule restricted to voiced geminates with a constraint against *velar* geminates. There is still consistent overlap, so that in the latter example, *voiced*, *velar* geminates would be marked off by both rule and constraint. Care is required here, however: overlap is not sufficient to draw a reasonable analogy because *all* rules and constraints have *some* overlap, even those with unrelated structural configurations, since one can always construct a representation that contains both of them. For

example, a constraint against front rounded vowels and an unrelated rule voicing intervocalic consonants overlap in forms like /basity/. Rather, a reasonable systematic analogy obtains when the structural configurations are satisfied by the same section of structure, as is the case for the rule degeminating voiced geminates and the constraint against velar geminates.<sup>44</sup> In general, then, connection can be made between rules and constraints on the basis of the structural configuration they mention.

Our brief comparison demonstrates that while rules and constraints are not formally identical, they can still be identified with each other, since both discriminate between phonological representations, by referring to structural configurations. We can take individual generalisations, or collections of marked feature combinations in vowels (Calabrese 1995), or the class of phonetically grounded constraints (Archangeli and Pulleyblank 1994), or schemata such as Alignment (McCarthy and Prince 1993a), and put them to the test both as markedness constraints and as structural descriptions of rules.

Having isolated the notion of strong analogy between Markedness constraints and the structural descriptions of rules, we may now use the notion to compare the interactions between rules with the interaction of constraints. Since strong analogy can be defined independently of questions of substantive content, we abstract away from questions of whether rules/constraints are simple or complex, plausible or implausible, universal or language-specific, and other details, so that we can conduct a formal comparison of the systems in which these questions are *embedded*. This maximises the generality of the study, so that it has relevance over and above all controversies among phonologists about exactly what structural configurations are involved, and

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<sup>44</sup> The “Phonological Level Hierarchy” (Paradis 1988) seems relevant here: the highest level of phonological structure (‘X’ timing units) is decisive in casting the analogy, whereas the features of voicing and velar place at lower levels in the structure are not decisive in drawing an analogy. Thus, rules/constraints with *geminate* configurations are all analogous, but rules that refer to *velar* geminates do not seem analogous to rules/constraints referring to labialised *velars*.

relevance across all subdomains of phonology. Failing to abstract the issue from these other considerations only holds up the advance of scholarship.<sup>45</sup>

## 4.2 An Analysis of Serial Rule Interaction

Having analysed the formal relationship between rules and constraints, we will now set out what we regard as the essentials of serial rule interaction. Once again, the basis for this is to consider rules as relations on the set of representations. This will clarify rule interaction, but also will lend itself to a fully generalised comparison with constraint interaction.

In a grammar based on rules, serial derivations are built up from the application of one operation after another, if the conditions on application of the rules (traditionally, the "structural description") allow. A structural description may be **met at the outset**, or it may be **met by feeding** when structure is altered by the application of some particular prior rule. It may be **left unaltered**, or it may be **subject to alteration** if, after a rule has applied, another part of the structure meeting its structural description is altered by the application of some particular subsequent rule. Without the full structural context at a later derivational stage or at the surface, it is not clear why the process should have applied - an apparent "overapplication" (Roca 1997b:8, Idsardi 2000:338, McCarthy 1999a:3). This has also been called "non-surface-apparent" opacity (McCarthy 1999a:2) because a piece of the surface structure that differs from the lexical

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<sup>45</sup>Thus we depart from the position of McCarthy (1999a) who claims, untenably, that it is impossible to give a *general* characterisation of where the two frameworks differ over the accommodation of certain patterns (in this case, generalisations that are non-surface-true): "On the OT side, the universality of constraints means that a markedness constraint [like ONSET] might be dominated for reasons that have nothing to do with opacity. And on the serialism side, the non-universality of rules means that we cannot in general know that generalisations like (i)[permitting onsetless syllables word-initially] are the result of derivational opacity instead of positing an epenthesis rule that is limited to medial syllables." (McCarthy 1999a:2-3 fn.1). For us, the question of universality should and *can* be kept separate. So of course we cannot *know* the rules of a language, but we do not need to maintain a studied uncertainty about the form of rules. Rather, we take a certain range of rule systems and consider whether all of them, or some subset, can be mapped into constraint systems without losing the same output.

source is attributed to a linguistic generalisation which is not itself apparent in that surface form, but takes effect at a level more abstract than the surface form itself.

For exemplification, let us confine our attention to the application of pairs of rules. The second rule's structural description might be met by the feeding of the first; the first rule's structural description might be rendered opaque by the second. This will give us four logical possibilities.

**(a) Both met at the outset; Both left unaltered** (mutually non-affecting)

One kind of pair of mutually non-affecting processes might be the formation of syllable nuclei from vowels and changes to vowel quality that are irrelevant to syllabification. In English, vowels are always tense when immediately followed by another vowel - e.g. *menial*, *various*, *affiliate*, *manual*, *graduate*, *tortuous*, *sensual* are [i,u] rather than lax [ɪ,ʊ] This may be specified by the following rule:

(3) English Prevocalic Tensing (Roca and Johnson 1999:567)

[-consonantal] → [+ATR] / \_\_\_\_\_ [-consonantal]

This rule will not alter the formation of syllable nuclei based on these vowels, nor will syllable nucleus formation alter the conditions giving rise to tensing – the two are mutually non-affecting.

**(b) Second met by feeding; Both left unaltered** (simple feeding)

Many structure-building operations feed and are met by feeding: formation of syllable nucleus feeds syllable onset formation; conditions for stress to be assigned to syllables are fed by the construction of syllables themselves. An example of a segmental process that may be fed by

other rules is postvocalic spirantisation in Tiberian Hebrew (Idsardi 1998). In (4), the obstruents are fricatives when in post-vocalic environment, but stops in other environments.

(4) Tiberian Hebrew spirantisation

kaaθáv 'he wrote'                      gaaðál 'he was great'

jixtóov 'he writes'                      jiydóol 'he is great'

In one feeding interaction, some post-vocalic obstruents arise through word-final degemination.

Geminates themselves do not undergo spirantisation (Schein and Steriade 1986), but degemination can lead to (i.e. feed) spirantisation, as in (5).

(5) Tiberian Hebrew Spirantisation met by feeding

a. rav                      'much/large sg.'

rabbim                      'many/large pl.'

b. Derivation of *rav*:

/rabb/

rab      Word-final Degemination

rav      Postvocalic Spirantisation

The conditions for both processes remain transparent - the right-hand environment of word-finality, and the left-hand environment of a preceding vowel.

**(c) Both met at the outset; First subject to alteration** (counterbleeding)

A productive example of this interaction is supplied by Serbo-Croat. Epenthesis is used to break up unsyllabifiable consonant combinations (6a). It is also the case in Serbo-Croat that /l/ vocalises to /o/ word-finally (6b). The conditions for both epenthesis and l-vocalisation are met by word-final /Cl/. Epenthesis occurs, but the condition for its occurrence is removed when the /l/ is vocalised in (6c).

## (6) Serbo-Croat (Kenstowicz 1994:90ff)

	Masculine	Feminine	Neuter	Plural	gloss
	mlad	mlad-a	mlad-o	mlad-i	'young'
	zelen	zelen-a	zelen-o	zelen-i	'green'
a.	ledan	ledn-a	ledn-o	ledn-i	'frozen'
	dobar	dobr-a	dobr-o	dobr-i	'good'
	jasan	jasn-a	jasn-o	jasn-i	'clear'
b.	debeo	debel-a	debel-o	debel-i	'fat'
	beo	bel-a	bel-o	bel-i	'white'
	mio	mil-a	mil-o	mil-i	'dear'
c.	okrugao	okrugl-a	okrugl-o	okrugl-i	'round'
	nagao	nagl-a	nagl-o	nagl-i	'abrupt'
	podao	podl-a	podl-o	podl-i	'base'

The conditions for vowel epenthesis in Eastern Massachusetts English may similarly become opaque (McCarthy 1991, 1999c, Halle and Idsardi 1997). Epenthesis breaks up unsyllabifiable consonant sequences of /j/ and a liquid. If the liquid is /r/, however, it is subject to coda *r*-deletion, removing the condition responsible for the epenthesis. Thus, *desire* is derived  $dɪzajɹ \rightarrow dɪzajəɹ \rightarrow dɪzajə$ , the underlying form /dɪzajɹ/ being supported by its rendering in the suffixed form *desirous* [dɪzajɹəs]. The altering of the conditions for epenthesis by consonant deletion is also found in analyses of Tiberian Hebrew (McCarthy 1999a).

In Tiberian and Modern Hebrew, the conditions for the formation of fricatives (spirantisation) may be subject to alteration (Idsardi 1997,1998). Fricatives occur following a vowel; plosives in other environments. However, fricatives survive even after their conditioning vowel is lost completely in syncope: Modern Hebrew *bi-saPor* (P a labial obstruent) → *bi-safor* (spirantisation) → [bisfor] (vowel syncope) ‘on counting’. Compare [lispor] ‘to count’.

Very commonly, vowels lengthen before voiced consonants, but it is also common that the postvocalic consonant itself is also altered, so that the voicing that conditions vowel length is not present in the surface representation (Dinnsen, McGarrity, O'Connor and Swanson 2000). This recurs not only cross-linguistically, but also during acquisition. In (7a), a child with a disordered phonology deletes final consonants that otherwise surface in an intervocalic context (7b). Since the consonants are omitted, the basis of the longer vowels for the forms on the left is absent.

(7) American English Child aged 7;2 (quoted in Dinnsen et al 2000)

a.	kæ:	'cab'	ka	'cop'
	kɪ:	'kid'	pæ	'pat'
	dɔ:	'dog'	dʌ	'duck'
b.	kæbi	'cabby'	kapou	'copper'
	kɪdou	'kiddo'	pæti	'patty'
	dɔgi	'doggy'	dʌki	'ducky'

Other children may reduce final consonants to glottal stops, again removing the voicing distinction that conditions vowel length. Similarly, American adults neutralise /t/ and /d/ to a flap, giving [ɹaɪrɫ] *writer* vs. [ɹaɪ:rɫ] *rider*, a minimal pair distinguished only by the resulting vowel length difference (Dresher 1981). Dinnsen et al (2000) concede that there could be some doubt as to whether vowel lengthening and consonant reduction are always discrete phonological alternations or, rather, effects of phonetic execution of the vowel-consonant sequences

concerned, given the phonetic motivations for the changes involved (Chen 1970, Port and Crawford 1989). A minimally different pattern in Canadian English is often cited, where /t/-/d/ neutralisation alters the conditions behind vowel *raising* before *voiceless* consonants, so that *writer* [ɹɪɪdəɹ] and *rider* [ɹaɪdəɹ] differ in the diphthong, but not in the following consonant (Joos 1942, Halle 1962, Bromberger and Halle 1989, Kenstowicz 1994:99-100). However, the low and raised vowels do not actually alternate -[ɹɪɪt]/[ɹɪɪdəɹ], [ɹaɪd]/[ɹaɪdəɹ] - and there are even a few examples of [a] that contrast with [ʌ] e.g. [saɪklaps] *cyclops*, although there are some alternations induced by voicing changes – [nɪɪf] *knife* but [naɪvz] *knives*. So, this pattern may be viewed as a subregularity of the lexicon, perhaps expressed by a ‘lexical rule’ (Kiparsky and Menn 1977). In conclusion, although the Serbo-Croat adjectival paradigm in (6) above seems to provide an instance where one general process alters the conditions that cause another, we have other examples in the literature that are not quite as robust, and which raise two, opposite, difficulties: they may represent historical developments in the lexicon of a language that do not reflect productive phonology, or; they may be entirely productive and well-motivated such that they could be conventionalised phonetic processes.

**(d) Second met by feeding; First subject to alteration**

The final possibility combines feeding and alteration of conditions into a single complex interaction between two processes. Although the phonology literature has not previously isolated and named this type, there are well-known examples of it.

One is from Klamath (Halle and Clements 1983:113, Clements 1985, Iverson 1989), already referred to in 1.2.1. Nasals change to laterals before a following lateral, but, in a sequence of two laterals, if the second lateral is voiceless or glottalised then the sequence is simplified to lateral-laryngeal [lh] or [lʔ]. The first process feeds the second by creating lateral-lateral

sequences, /n/ → l̥ → [lh] and /nʲ/ → l̥ʲ → [lʲ], but the second process destroys the original lateral that is the condition for the first process, rendering it opaque.

Another example is from Turkish (Orgun and Sprouse 1999, Sprouse, Inkelas and Orgun 2001). Epenthesis breaks up consonant clusters in Turkish, e.g. *devr-i* ‘transfer’-acc. but *devir* ‘transfer’-nom. Epenthesis applies between consonant-final stems and consonant suffixes such as the 1sg. possessive suffix *-m* as shown in (8).<sup>46</sup>

(8) Turkish (Kenstowicz and Kisseberth 1979:192)

	Abs. sg.	Abs. pl.	3sg. Poss.	1sg. Poss.	Gloss
a.	<i>arı</i> <i>araba</i>	<i>arı-lar</i> <i>araba-lar</i>	<i>arı-sı</i> <i>araba-sı</i>	<i>arı-m</i> <i>araba-m</i>	‘bee’ ‘wagon’
b.	<i>kız</i> <i>yel</i>	<i>kız-lar</i> <i>yel-ler</i>	<i>kız-ı</i> <i>yel-i</i>	<i>kız-ı-m</i> <i>yel-i-m</i>	‘daughter’ ‘wind’
c.	<i>ayak</i> <i>inek</i> <i>kuyruk</i>	<i>ayak-ler</i> <i>inek-ler</i> <i>kuyruk-lar</i>	<i>aya-ı</i> <i>ine-i</i> <i>kuyru-u</i>	<i>aya-ı-m</i> <i>ine-i-m</i> <i>kuyru-u-m</i>	‘foot’ ‘cow’ ‘tail’

With vowel-final stems (8a), no epenthetic vowel is necessary in the 1sg. Possessive, rather it occurs with consonant-final stems (8b). In (8c), the final *k* of a polysyllabic stem is deleted intervocalically (Zimmer 1975), but stems with deleted final *k* take an apparently unnecessary epenthetic vowel in the 1sg. possessive. In these cases, epenthesis leaves stem-final *k* in an intervocalic environment and thereby feeds *k*-deletion, and in turn, deletion of the *k* removes the overt motivation for epenthesis.

<sup>46</sup>The traditional description of Turkish gives a maximal suffix form *-Im* and claims that the vowel is deleted following another vowel (Kornfilt 1997). The opposite analysis, where the suffix is taken to be *-m*, and vowel epenthesis is used to break up consonant clusters, is taken up by Inkelas and Orgun (1995) on the evidence of word minimality effects.

The interactions (a)-(d) discussed so far employ 'unbridled' serialism: rules apply if their structural descriptions are met. This can be done by ordering of the two rules consistently with their order of application, or it can be done in the absence of ordering. This alone leads to the possibilities of feeding, and of apparent overapplication. Further patterns can be generated when alternative rule ordering constraints cause some rules not to apply as expected. A rule whose structural description is met may still never apply, if it is ordered too early, or too late. Thus, a rule will not apply if it is **met by feeding** but is ordered before the rule that feeds it, rather than after. This is *counterfeeding*, and since the rule fails to apply while the structural context for it is present at subsequent derivational stages, it entails the apparent "underapplication" of the rule (Idsardi 2000:338). Whereas overapplication is a natural possibility in serial derivation, underapplication follows only from the presence of constraints that rule out application. A rule might also never apply if its structural description can be **altered** by another rule when the rule that renders the structural description opaque is ordered before rather than after. For two rules R1 and R2 whose structural descriptions are both met at some stage, R1 *bleeds* R2 if R1 applies first and removes the context for R2 to apply. Two changes are only produced when the rules apply in *counterbleeding* order, R2 then R1, running counter to bleeding order (interaction (c)). Although bleeding, like counterfeeding, involves the prevention of rule application, it does not constitute apparent underapplication. The non-application of a bled rule is not opaque, because its non-application at later stages is consistent with the fact that its structural description is not met at later stages.

We summarise the possible interactions in the table in (9), giving the names of the unconstrained order of application with a capital (Feeding, etc.) and that of the constrained order of application without a capital (bleeding, etc.).

(9)

	<b>Both met at outset</b>	<b>Second met by feeding</b>
<b>Both left unaltered</b>	(a) (no interactive effect)	(b) Simple Feeding  / counterfeeding
<b>First altered</b>	(c) Counterbleeding  / bleeding	(d) Overapplication-Feeding  / counterfeeding

Recent work examining phonological rule interactions repeatedly overlooks what we call overapplication-feeding (Roca 1997b, Kager 1999, McCarthy 1999a, Idsardi 2000). It seems that the four-way terminological distinction between feeding, counterfeeding, bleeding, and counterbleeding rule orders used by phonologists leads to the erroneous assumption that the effect of overapplication arises solely in counterbleeding. The analysis of rule interaction here overcomes this weakness.<sup>47</sup>

A further advantage may accrue to this account. It has been noted (McCarthy 1999a) that the literature on rule interaction and rule ordering in generative phonology has focussed on pairs of rules, and concomitantly failed to test whether complex interactions between larger sets of rules overgenerate or undergenerate in comparison to empirically attested sound patterns. Perhaps study of larger rule sets has been hampered by the lack of a fully adequate description of rule interactions. The present account, already proven superior as an account of pairwise interactions, might be extended to describe the interaction of multiple rules since they pick out the relationship between each rule's structural description and the effects of preceding rules (feeding) and subsequent rules (alteration).

<sup>47</sup>Two more arcane possibilities suggest themselves, neither of which is amenable to serial rule interaction. Two processes might each appear to be fed by the other, and yet both apply (see 4.3.2). Two processes might each alter the context of the other, and yet both still apply (cf. Hyman 1993).

### 4.3 Rule Interaction Versus Constraint Interaction

#### 4.3.1 Translation from Rules to Constraints

Having set out and exemplified serial rule interactions, we will examine them in abstract form enabling a general translation to patterns of constraint interaction.

#### (10) Two Rule Applications

Consider a representation  $p_0$ .

Let  $p_1$  be a representation derivable from  $p_0$  by means of some operation O1.

Let  $p_2$  also be a representation derivable from  $p_0$  by means of some operation O2.

Suppose, for simplicity, that O1 and O2 alter *distinct* pieces of the structure in  $p_0$ .

Let  $p_{12}$  be the representation that results from employing both O1 and O2.

In the terms of chapter three, such a mapping will be representative and veritable, so operations will not be obscured by their use in combination with each other. In general, then, the numeral subscripts indicate which changes have been incorporated into the representation relative to  $p_0$ .

Employing O1 and O2 in either order leads to  $p_{12}$ , as (11) illustrates.

$$(11) \quad \begin{array}{ccc} p_0 & \xrightarrow{O1} & p_1 \\ \downarrow_{O2} & & \downarrow_{O2} \\ p_2 & \xrightarrow{O1} & p_{12} \end{array}$$

Using (11) as our base, we now reconsider the four interactional possibilities (a)-(d) in abstract form. They are represented by the four pairs of rules shown in (12).<sup>48</sup>

(12)

**(a) Both met at outset; both left unaltered**

Rules: R1:  $p_0 \rightarrow p_1; p_2 \rightarrow p_{12}$  R2:  $p_0 \rightarrow p_2; p_1 \rightarrow p_{12}$

Derivation:  $p_0 \xrightarrow{R1} p_1 \xrightarrow{R2} p_{12}$  or  $p_0 \xrightarrow{R2} p_2 \xrightarrow{R1} p_{12}$  or  $p_0 \xrightarrow{R1,R2} p_{12}$ .

**(b) One met by feeding; both left unaltered**

Rules: R1:  $p_0 \rightarrow p_1; p_2 \rightarrow p_{12}$  R2:  $p_1 \rightarrow p_{12}$  only

Derivation:  $p_0 \xrightarrow{R1} p_1 \xrightarrow{R2} p_{12}$  (if R1 precedes R2: feeding);

$p_0 \xrightarrow{R1} p_1$  (if R2 precedes R1: counterfeeding)

**(c) Both met at outset; one altered**

Rules: R1:  $p_0 \rightarrow p_1$  only R2:  $p_0 \rightarrow p_2; p_1 \rightarrow p_{12}$

Derivation:  $p_0 \xrightarrow{R1} p_1 \xrightarrow{R2} p_{12}$  (if R1 precedes R2: counterbleeding);

$p_0 \xrightarrow{R1,R2} p_{12}$  (if R1,R2 unordered: simultaneous)

$p_0 \xrightarrow{R2} p_2$  (if R2 precedes R1: bleeding)

**(d) One met by feeding; the other altered**

Rules: R1:  $p_0 \rightarrow p_1$  only R2:  $p_1 \rightarrow p_{12}$  only

Derivation:  $p_0 \xrightarrow{R1} p_1 \xrightarrow{R2} p_{12}$  (if R1 precedes R2: overapplication feeding)

$p_0 \xrightarrow{R1} p_1$  (R2 precedes R1: counterfeeding)

Mutually non-affecting rules (12a) may apply to any of the forms in (11). In a simple feeding interaction (12b), the second rule could not apply to  $p_0$  but it can apply to  $p_1$  after the first rule

<sup>48</sup>We assume in all four cases (a)-(d) that the representation  $p_{12}$  is not subject to the further application of the rules.

has applied. In a counterbleeding interaction (12c), the first rule can only apply first to  $p_0$  otherwise it cannot apply. Overapplication feeding (12d) is a combination of the previous two. This specifies the possible interactions between rules at the greatest possible level of generality, even more so than the schematised versions of context-sensitive string-rewriting rules,  $A \rightarrow B/X\_Y$  and the like, that persist in general discussion of phonological rules (Roca 1997b:3ff, Halle and Idsardi 1997:345, Idsardi 1997:373, McCarthy 1999a, 2003). Having specified the pairs of rules in this way, we can now translate them into the strongly analogous constraints. This will demonstrate with full generality which rule interactions are replicated by constraints and which are not. Recall that a constraint is strongly analogous to some rule if it is violated by precisely those forms which would be subject to the application of the rule (see 4.1). This means that if a rule applies to  $p_0$ , for example, then  $p_0$  will violate the strongly analogous constraint and will be less harmonic than other forms.

**(13) Type (a) Both met at outset; both left unaltered**

Rules:            R1:  $p_0 \rightarrow p_1; p_2 \rightarrow p_{12}$     R2:  $p_0 \rightarrow p_2; p_1 \rightarrow p_{12}$

Constraints:    C1:  $p_0, p_2 \prec p_1, p_{12}$     C2:  $p_0, p_1 \prec p_2, p_{12}$

Tableau:

	C1	C2
$p_0$	*	*
$p_1$		*
$p_2$	*	
$p_{12}$		

Just as order of application made no difference to the outcome of the rules (12a), so ranking does not affect the evaluation of forms against C1 and C2, since they do not conflict over any forms.

Ranking would merely settle the non-crucial matter of relative harmony among suboptimal forms,  $p_1 \prec p_2$  or  $p_2 \prec p_1$ .

**(14) Type (b) One met by feeding; both left unaltered**

Rules: R1:  $p_0 \rightarrow p_1; p_2 \rightarrow p_{12}$  R2:  $p_1 \rightarrow p_{12}$  only

Constraints: C1:  $p_0, p_2 \prec p_1, p_{12}$  C2:  $p_1 \prec p_0, p_2, p_{12}$

Tableau:

	C1	C2
$p_0$	*	
$p_1$		*
$p_2$	*	
$p_{12}$		

The constraints rate  $p_{12}$  better than  $p_1$  on any ranking – matching the outcome of the rules in feeding order. Neither ranking of constraints correlates in outcome with the counterfeeding order of rules.

In (15), we introduce Faithfulness constraints F1 and F2. Since  $p_1$  and  $p_2$  differ from  $p_0$ , there must be for each a violation of some Faithfulness constraint (only an identity mapping lacks any Faithfulness constraint violations). In order for the processes to go ahead, these Faithfulness constraints are ranked below the respective Markedness constraints C1 and C2, but their influence is felt here because the relevant Markedness constraints fail to discriminate between  $p_2$  and  $p_{12}$ .

## (15) Type (c) Both met at outset; one altered

Rules: R1:  $p_0 \rightarrow p_1$  only      R2:  $p_0 \rightarrow p_2; p_1 \rightarrow p_{12}$

Constraints: C1:  $p_0 \prec p_1, p_2, p_{12}$       C2:  $p_0, p_1 \prec p_2, p_{12}$

F1:  $p_1, p_{12} \prec p_0, p_2$       F2:  $p_2, p_{12} \prec p_0, p_1$

Tableau:

	C1	C2	F1	F2
$p_0$	*!	*		
$p_1$		*!	*	
$p_2$				*
$p_{12}$			*!	*

The strongly analogous constraints C1 and C2 alone leave both  $p_2$  and  $p_{12}$  as maximally harmonic, precisely matching the fact that neither of the analogous rules would apply to  $p_2$  or  $p_{12}$ . However, when we consider the ever-present Faithfulness constraints we observe that  $p_2$  will be optimal because it is more faithful. This means that the constraint interaction coincides with the bleeding interaction by which R2 would produce  $p_2$ . Any ranking of the analogous constraints achieves that same outcome, so the counterbleeding rule interaction, which produces  $p_{12}$ , is not replicated.

(16) **Type (d) One met by feeding; the other altered**Rules: R1:  $p_0 \rightarrow p_1$  only R2:  $p_1 \rightarrow p_{12}$  onlyConstraints: C1:  $p_0 \prec p_1, p_2, p_{12}$  C2:  $p_1 \prec p_0, p_2, p_{12}$ F1:  $p_1, p_{12} \prec p_0, p_2$  F2:  $p_2, p_{12} \prec p_0, p_1$ 

Tableau:

	C1	C2	F1	F2
$p_0$	*!			
$p_1$		*!	*	
$p_2$				*
$p_{12}$			*!	*

The tableau is rather similar to that in (15), where the strongly analogous constraints leave both  $p_2$  and  $p_{12}$  as maximally harmonic, but  $p_2$  is more faithful. This time, the tableau outcome is entirely at variance with the outcome of the rules in either order. R1 followed by R2 gives  $p_{12}$ , but a counterfeeding order would give  $p_1$ .

The comparison thus far is summarised in the table (17):

(17)

Outcome of rules replicated?	Both met at outset	One met by feeding
<b>Both left unaltered</b>	YES	Simple Feeding – YES / counterfeeding - NO
<b>One altered</b>	Counterbleeding - NO / bleeding - YES	Overapplication Feeding - NO / counterfeeding - NO

Rules that are left transparent pose no difficulty for replication in terms of constraints. This holds whether they are both met at the outset or one met by feeding. In contrast, where structural descriptions are altered the outcome is not replicated. This holds whether they are both met at the outset or one met by feeding. So this possibility is a distinctive feature of rule interaction not shared by constraint interaction. Furthermore, when rule ordering constrains rule applications that would otherwise proceed, bleeding, which is transparent, *is* replicated, but counterfeeding, which creates apparent underapplication, is not. Finally, we may observe that the outcome of overapplication-feeding-pattern rules (one met by feeding, one altered) is not replicated at all for either the unconstrained or constrained orders of application.

A formal comparison based on strongly analogous rules and constraints demonstrates that the two frameworks make different predictions as to the *outcomes that would follow from the same pair of linguistic generalisations being present in a grammar*. So far, this favours serial rule application since there is empirical support for the overapplication effects it creates (counterbleeding, and overapplication-feeding) given earlier in 4.2.1. In both subtypes we have the instantiation of a double-change to  $p_{12}$  from the basic representation  $p_0$ , rather than a single change to  $p_2$  as predicted by constraint evaluation. In a constraint evaluation, we would have to find an additional constraint or constraint interaction mechanism, to eliminate  $p_2$  and get the desired result  $p_{12}$ . In this way, there may be strategies in optimality theoretic analysis that reproduce the same patterns as serial rule interactions for certain restricted subcases, but not in general. Extensions of optimality theory, Sympathy theory (McCarthy 1999a) and Enriched Input theory (Sprouse, Inkelas and Orgun 2001) achieve simulation of serial rule interaction in many cases, but (for better or worse) not all, so the similarities fall short of isomorphism.

While there are effects of serial rule interaction that are not directly replicated by constraint interaction, the same is true the other way, as we now show.

### 4.3.2 Mutual Interdependence

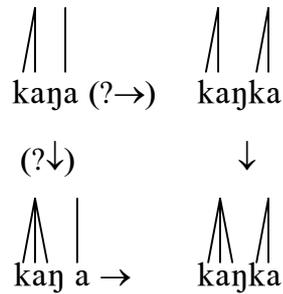
One possible - and attested - pattern that does not fall into the range of interactions already considered is that of mutually interdependent generalisations. This pattern will not work as a serial rule interaction, since paradoxically each would appear to be fed by the other, but it can be made to work as a constraint interaction.

An example of this is provided by one aspect of the Lardil nominative pattern (Prince and Smolensky 1993:102-103,124-125), where coda syllabification and onset augmentation work in this way. In the uninflected nominative, short stems are subject to word-final augmentation to bring them up to the minimum disyllabic word form, but if the stem-final consonant is a licit coda of the language - either a nasal homorganic to the following onset (17a.,b.), or a nonapical coronal (17c.) - then the stem is augmented not only with the epenthetic vowel *a* but also with an accompanying epenthetic onset. If, however, the stem-final consonant is not a licit coda (17d.) then it is placed in the onset itself.

(17)	Stem	Nominative	Gloss
a.	/kaŋ/	.kaŋ.ka. (*.ka.ŋa.)	'speech'
b.	/tʰaŋ/	.tʰaŋ.ka. (*.tʰa.ŋa.)	'some'
c.	/maɾ/	.maɾ.ta. (*.ma.ɾa.)	'hand'
d.	/yak/	.ya.ka.	'fish'

The following diagram (18) represents the coda syllabification operation (downwards) and onset augmentation operation (rightwards) for (17a) [.kaŋ.ka.]. The operations are shown mapping from a basic form (containing only the uncontroversial syllabifications of the segments /k/,/a/, and epenthetic /a/) to the surface form.

(18)



The difficulty is that each operation is dependent on the other, as if each were fed by the other.

For nasals can only be syllabified in the coda in Lardil in the presence of a following homorganic onset. Augmentation of an onset only occurs if the stem consonant is syllabified in the coda (otherwise the stem consonant forms the onset). So each could apply to the intermediate representation where the other operation had applied - coda syllabification in the presence of a homorganic onset / augmentation of homorganic onset after stem consonant coda syllabification - yet neither could apply to the initial representation in (18). This means that the intermediate representations themselves are unobtainable derivationally, so that a serial analysis is logically precluded. As Prince and Smolensky (1993:124-125) recount, neither cyclic, ordered, nor persistent syllabification rules would place a stem nasal in the same syllable as the rest of the stem. This is not a problem for (17c) .maɾ.ta. since /r/ is always a licit coda and might be put in the coda on one cycle, and epenthetic .ta. added on the next. It is not a problem for (17d) .ya.ka. since /k/ is a completely illicit coda, so would go straight in the onset. Unable to sanction a nasal coda, a derivational system would inevitably make (17a) pattern with (17d): \*.ka.ŋa. . Not so with a constraint system.

When we consider this kind of interaction in terms of four representations  $p_0, p_1, p_2, p_{12}$  related to one another as before, we have the following.

(19) **Both met by feeding (Mutual Interdependence)**Rules: R1:  $p_1 \rightarrow p_{12}$  only R2:  $p_2 \rightarrow p_{12}$  onlyConstraints: C1:  $p_1 \prec p_0, p_2, p_{12}$  C2:  $p_2 \prec p_0, p_1, p_{12}$ 

Tableau:

	C1	C2
$p_0$		
$p_1$	*!	
$p_2$		*!
$p_{12}$		

The strongly analogous constraints C1 and C2 rule out  $p_1$  and  $p_2$  respectively, but fail to distinguish between  $p_0$  and  $p_{12}$ . If it were then a matter of faithfulness, then the constraint system would deliver maximally faithful form  $p_0$  – just as the rule system would simply fail to modify  $p_0$  with the rules R1 and R2.

Adopting *ad hoc* constraints which describe the conditions which prompt the two processes of onset augmentation and coda placement in (18) creates the situation in (20). We have: \*C.V, which rules out a coda consonant followed by an onset syllable (forcing C-epenthesis) and PARSEN/\_[T, which rules out unsyllabified nasals before a homorganic stop onset.

(20)

	*C.V	PARSEN/_[T
		
		*!
	*!	
		

If we were to add the very simple proviso that segments may not be left unsyllabified (\*STRAY, Clements 1997:318), the first form will be ruled out. The optimality of .kaŋ.ka. at the expense of other possibilities like \*.ka.ŋa. (where the ŋ is placed in the onset), etc. can be achieved with the constraints ALIGNR(Stem,Syllable) “the right edge of every stem coincides with the right edge of a syllable”, ONSET “syllables have onsets”, CODA-COND “nasals only go in the coda if homorganic to a following stop”, NOCOMPLEX “onset and coda each contain no more than one consonant” (cf Prince and Smolensky 1993:118). These constraints also subsume our original formulations \*C.V (subsumed by ONSET) and PARSEN/\_[T (subsumed by \*STRAY) which described the particular conditions for the two processes considered here, corresponding more directly to the putative - but completely unsuccessful - rules.

Other instances of mutually interdependent processes have been cited in the optimality theory literature (McCarthy 1993b:1), and have been dubbed “chicken-egg effects” (McCarthy 2002:144). In Southern Paiute, reduplicative prefixes are formed by copying the initial CV or CVC of the root to form a syllable, but nasals are admitted into syllable coda only if they agree with a following stop or affricate. These two conditions are mutually interdependent, so that in

*wi-winni* ‘to stand’ the *n* is not copied since it fails the coda condition, but in *pim-pinti* ‘to hang onto’ it is copied but must be *m* so that it is assimilated to the following *p*. In serial terms, “it is impossible to know how much to copy until nasal assimilation has applied, but it is impossible to apply nasal assimilation unless the nasal has been copied” (McCarthy 2002:144). For cases of mutually interdependent processes, a constraint system provides a solution where a rule system cannot.

Thus far, then, each system offers descriptive capacity that cannot be replicated by the other. Serial rule interaction alone offers the possibility of overapplication, by allowing a structural description to be altered by another rule, and constraint interaction alone offers the possibility of mutual interdependent processes, by evaluating candidates against different conditions simultaneously rather than just one.

### 4.3 Conflicting Structural Outcomes

In all the cases seen, which are pairwise interactions that occur when two processes affect different pieces of the same structure, rank order between the strongly analogous constraints never makes a difference. We will now consider cases where two processes offer opposite structural outcomes.

#### 4.3.1 Reciprocal Outcomes

Suppose that two constraints, that are each responsible for processes in a language, conflict. That is, for some representations  $p_0$  and  $p_1$ , one constraint C1 evaluates  $p_0$  suboptimal and the other C2 evaluates  $p_1$  suboptimal. Given  $p_0$  as an input, only the ranking of C1 and C2 can decide whether  $p_0$  or  $p_1$  is optimal.

Strongly analogous rules supporting the same reciprocal outcomes would employ mutually-reversing structural changes. If both apply, R2 literally reverses the mapping of R1,

mapping from  $p_1$  back to the original representation  $p_0$  - a Duke of York gambit so-called by Pullum (1976), though here we are only considering a simple subcase of the Duke of York gambit, where there are no intervening rules making other changes to the representation and where each structural change is the exact inverse of the other (we shall relax this latter condition in the next section, 4.3.2). In this simple case, we have a straight conflict between the two possible outcomes  $p_0$  and  $p_1$  in both a serial rule account and a ranked constraint account, and under these conditions serial rule order and rank order of constraints *do*, finally, correlate with each other over the possible outcomes.

(21) **Reciprocal Outcomes** (a simple “Duke-of-York gambit”)

Rules:            R1:  $p_0 \rightarrow p_1$     R2:  $p_1 \rightarrow p_0$

Derivations:         $p_0 \xrightarrow{R1} p_1 \xrightarrow{R2} p_0$  (R1 precedes R2)

$p_0 \xrightarrow{R1} p_1$  (R2 precedes R1)

$p_0 \xrightarrow{R1} p_1 \xrightarrow{R2} p_0 \xrightarrow{R1} p_1 \xrightarrow{R2} p_0 \dots$  (R1,R2 unordered)

Constraints:    C1:  $p_0 \prec p_1$     C2:  $p_1 \prec p_0$

Tableaux:

	C1	C2	FAITH
$p_0$	*!		
$p_1$		*	*
	C2	C1	FAITH
$p_0$		*	
$p_1$	*!		*

Then we have a correlation between the two forms of interaction. The outcome  $p_0$  comes from C1 is dominated by C2 and from R1 precedes R2; while the outcome  $p_1$  comes from C2 is dominated by C1 and from R2 precedes R1. In this very specific case of exactly reciprocal outcomes, we have a kind of structure preservation across serial rule grammars and constraint evaluation grammars, in as much as the relative order of the analogous grammatical elements matches the outcomes.

#### 4.3.2 *Sub-reciprocal Outcomes*

The match between serial rule interaction and ranked constraint interaction quickly falls down when we consider a variant on the reciprocal-outcomes pattern, however. Consider deletion and insertion. If deletion can affect any one of a class of phonemes in some context, it is nevertheless the case that insertion can only ever put one particular phoneme in. In many languages, syncope processes take out vowels and epenthesis processes put vowels in. If syncope and epenthesis rules were to apply one after the other in the same context, the vowel contrasts would all collapse and only the epenthetic vowel quality would be attested there, e.g.  $\{i,e,a,o,u\} \rightarrow \emptyset \rightarrow \{i\}$ , as discussed in 3.4.4. However, *ranked constraint interaction would not allow the inventory to collapse in this way*. Instead, if a phoneme is to occur in a given context, default features will not be used because faithfulness constraints will retain the original features.

There is a difference between rules and constraints here. In this kind of pattern, we have a *set* of outcomes  $p_0, p_0', p_0'', p_0'''$ .. set against an alternative  $p_1$  (e.g. forms with vowels present vs. forms identical but for the lack of a vowel). This generalises the simpler cases of exactly reciprocal outcomes  $p_0$  and  $p_1$ . In (22), we demonstrate the general divergence between the systems under these general conditions.

## (22) Sub-reciprocal Outcomes

Rules: R1:  $p_0 \rightarrow p_1$   $p_0' \rightarrow p_1$   $p_0'' \rightarrow p_1$   $p_0''' \rightarrow p_1 \dots$  R2:  $p_1 \rightarrow p_0$

Derivations:  $p_0' \xrightarrow{R1} p_1 \xrightarrow{R2} p_0$  (R1 precedes R2)

$p_0 \xrightarrow{R1} p_1$  (R2 precedes R1)

$p_0 \xrightarrow{R1} p_1 \xrightarrow{R2} p_0 \xrightarrow{R1} p_1 \dots$  (non-terminating, R1,R2 unordered)

Constraints: C1:  $p_0, p_0' < p_1$  C2:  $p_1 < p_0, p_0'$

Tableaux:

$/p_0/$	C1	C2	FAITH
$p_0'$	*!		
$p_1$		*	*
$p_0$	*!		**

$/p_0/$	C2	C1	FAITH
$p_0'$		*	
$p_1$	*!		*
$p_0$		*	*!*

On one order, R2 precedes R1 / C2 dominated by C1, the result is the same:  $p_1$ . On the other order, a difference is found: if R1 precedes R2, the rules collapse the inventory  $p_0, p_0', p_0'', p_0''' \dots$  down to  $p_0$ . However, if C1 is dominated by C2, the original members of the inventory are preserved, as the tableaux show. The constraints will not collapse the inventory.

The rule theory predicts that the existence of processes with sub-reciprocal outcomes can cause an inventory of possibilities to collapse down to the default possibility. The constraints theory predicts that, in languages with two processes with sub-reciprocal outcomes, inventories cannot collapse in any context.

The prediction of constraint theory is borne out. As argued in 3.4.4, inventories do not collapse in certain positions. Where syncope and epenthesis are both attested, as in Yawelmani Yokuts, their application is disjoint, specifically precluding inventory collapse:

Vowel Epenthesis inserts a vowel in just those contexts where failure to do so would yield an unpermitted consonant cluster. On the other hand, Vowel Deletion serves to delete just those vowels *not* required by the constraints on consonant clustering. Observe that the context VC\_CV *excludes* all the environments where deletion of the vowel would yield unpermitted clustering: - \*#CC, \*CC#, \*CCC. (Kisseberth 1970a:298-299)

So in the data in (23), both /i/ and /a/ (the two commonest vowels in Yokuts) are syncopeated, but there are no occurrences in the language of vowels being replaced by epenthetic /i/ resulting from syncope and epenthesis applying in series:

(23) Kisseberth (1970a)

hall-hat*in*-i:n → [hallatnen] \*hallitnen \*hillitnen \*hallitnin \*hillitnin

‘lift up’-desiderative-future

kili:y-**a**-ni → [kileyni] \*kiliyni

‘cloud’-protective-indirect.objective

Thus, constraints supporting the presence of vowels in C\_CC contexts (maximum retention of consonants *plus* restriction to just one consonant in syllable onset and one in syllable coda:

MAX-C and NOCOMPLEXONSET/CODA) win out over the constraint favouring absence of medial short vowels generally (minimisation of syllables outside of a maximally simple foot structure: PARSE-Syllable-to-Foot), so syncope can only occur in contexts other than those which would

produce CCC, that is in VC\_\_CV contexts. If the maximum retention of consonants (MAX-C) also dominates DEP-V, then consonant deletion will not be used to break up untenable consonant clusters, vowel epenthesis will. Then the minimisation of syllables outside feet is a *default* generalisation, and syncope applies as a default. And vowel quality of short medial vowels where they still occur is settled by faithfulness to the qualities provided by underlying forms.

Constraints on syllable structure tell us why epenthesis would apply (if needed to break up unsyllabifiable consonant clusters) and why syncope would be blocked (to avoid creating unsyllabifiable consonant clusters) in one fell swoop. The generalisation that syncope applies if the result is syllabifiable but is blocked just in case the output has *unsyllabifiable* consonants holds true across different languages with different syllable canons (Myers 1991:318), including English (e.g. Kenstowicz 1994:48), Amerindian languages Yokuts (Kisseberth 1970a) and Tonkawa (Kisseberth 1970b), Uto-Aztecan Southeastern Tepehuan (Kager 1997), Semitic languages Egyptian Arabic (Broselow 1976), Tiberian Hebrew (McCarthy 1979), Palestinian Arabic and Maltese (Brame 1974).

Rule theory, in addition to making the odd prediction that it is possible to have a Yokuts-like language in which syncope is less restricted, leading to words filled with epenthetic vowels like *\*hillitnin*, faces the further problem in Yokuts itself as to how to restrict syncope correctly so that its application and that of epenthesis are disjoint. One could follow McCarthy (1979), who proposes that "a phonological rule may apply if and only if its output conforms to the canonical syllable structures of the language"<sup>49</sup>. For this to work, however, conformity to syllable structure must be settled by checking the output of syncope against syllabification

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<sup>49</sup>This statement could be interpreted as saying that the syllable structure of the language defines a series of derivational constraints on sequences of C's and V's, which could then be used for local blocking of unacceptable cluster formations, as per Kisseberth. However, no-one has explicitly suggested this, and it does not make sense of McCarthy's theory that syllable structure preservation depends on the "basic mechanism" that syllabification is "repeated throughout the course of the derivation" (McCarthy 1979:13), and requires that "a rule may apply if and only if its output can be syllabified by the syllable canons of the language" (McCarthy 1979:33). These tend to imply the interpretation in the main text.

rules to see whether the surrounding consonants can be resyllabified to neighbouring syllables. And it must specifically be the onset and coda **formation rules** that are taken into consideration, and not epenthesis or stray erasure (consonant deletion) operations, for if stray erasure of unsyllabified consonants or syllabification of consonants by vowel epenthesis  $\langle C \rangle \rightarrow .CV$  is included in the subsequence, then all phoneme strings are syllabifiable ultimately and syncope will never be blocked. This is an added dimension of complexity antithetical to the basic derivational approach of computing step by step (Chomsky 1998, see 2.2.1 above). In a system of constraints, the same constraint on syllable form (NOCOMPLEXONSET/CODA) will both trigger epenthesis and block syncope, and this analysis will intrinsically guarantee their disjoint application.

One case I am aware of that might be construed as supporting the rule theory's prediction that inserted material may replace deleted material is in Icelandic. *Cr* clusters are broken up by *-u-* epenthesis, while others (*Cv* or *Cj*) are simplified by deletion. Both processes are present in the following noun paradigms (Kenstowicz 1994:79):

(24)		'medicine'	'storm'	'bed'	'song'
	nom.sg.	lyf-u-r	byl-u-r	beð-u-r	söng-u-r
	acc.sg.	lyf	byl	beð	söng
	gen.sg.	lyf-s	byl-s	beð-s	söng-s
	dat.pl.	lyfj-um	bylj-um	beðj-um	söngv-um
	gen.pl.	lyfj-a	bylj-a	beðj-a	söngv-a

Deletion simplifies the stem in the first three rows, e.g. *bylj* to *byl*, but in the nominative singular, *u*-epenthesis also applies. We could have had deletion blocked, and *j* parsed in the syllable nucleus to give *.by.li-r.*, but instead deletion and epenthesis both occur. On grounds unrelated to

the issue at hand, Itô (1986:187) attributes *-u-* epenthesis to the word *stratum*, but the deletion of *j* as an effect of syllabification of the stem that applies in the lexical *stratum*, which precedes the word *stratum*. Then genitive singular *byl-s* has *j* deleted as a lexical process, as does nominative singular *byl-r*, though only the latter receives the epenthetic *-u-* at the word level. By contrast, the *j* in the dative plural *bylj-um* is not deleted since it is syllabifiable as an onset. If so, it would show that the default interaction holds sway between opposite outcomes *within a given domain of application*. Even this may not be necessary, however, since one could put the case that in Icelandic *j* is a consonant, a palatal approximant, which - just like *v* in the stem *söngv* – will not be permitted to vocalise and form a syllable nucleus. Then *j*-deletion and *u*-insertion do not count as sub-reciprocal outcomes at all.<sup>50</sup>

#### 4.3.3 *The Extent of Structure Preservation Between Rules and Constraints*

We have argued that the conflict between sub-reciprocal outcomes universally produces default generalisations as predicted by constraint interaction, and not the feeding effect predicted by rule interaction. Thus we have distinguished the case of *sub*-reciprocal outcomes, where rule interaction and constraint interaction differ, from *exactly* reciprocal outcomes, for which serial order and rank order bring about the same effects. The extent of the structure preservation is now summed up in the text boxes following.

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<sup>50</sup> In many languages, it is clear that sounds transcribed as /j,w/ are realisations of high vowels that are positioned in syllable onset (Hayes 1989, Rosenthal 1994, Roca 1997c). For an argument in favour of the existence of consonantal approximants /j,w/ as distinct from high vowels /i,u/ in Bantu, see Zoll (1995).

### Rules with Exactly Reciprocal Outcomes

Let  $R1$  be a one-to-one function, then the inverse of  $R1$ , that is  $R1^{-1}$ , is also a function. *For example:*

- A vowel deletion process is not a one-to-one function, it is many-to-one, for it rewrites any vowel to zero,  $\{i,e,a,o,u\} \rightarrow \emptyset$ . When inverted this gives  $\emptyset \rightarrow \{i,e,a,o,u\}$ , which does not map to a unique output, so is not a function - unlike real epenthesis processes e.g.  $\emptyset \rightarrow i$ , which are functions.
- English coda  $r$ -deletion (Halle and Idsardi 1997), however, is a one-to-one function, for only  $r$  is rewritten as zero,  $r \rightarrow \emptyset$ . This has an inverse which is a function, which maps  $\emptyset$  to  $r$ .

*Only a rule which is a one-to-one function may have a counterpart rule whose outcome is exactly reciprocal.* This is the case if, given  $R1$ , a one-to-one function, there is a rule  $R2$  which is a one-to-one function such that  $R2$  intersects with  $R1^{-1}$ .

- $r$ -insertion (Halle and Idsardi 1997) reverses coda  $r$ -deletion.

### Conditions for Structure Preservation

For any rule  $x$ , let  $x'$  be the strongly analogous constraint. For any pair of rules  $x,y$ , say that  $[xy] = x$  precedes  $y$ ;  $\{x'y'\} = x'$  is dominated by  $y'$ . If  $p$  is a representation, say that  $xy(p)$  and  $x'y'(p)$  are the outcomes of the grammars  $xy$  and  $x'y'$  given  $p$ .

If  $a,b$  are one-to-one functions such that  $b$  has a non-empty intersection with  $a^{-1}$  (and  $a$  with  $b^{-1}$ ), then, for  $x,y \in \{a,b\}$ ,  $[xy](p) = \{x'y'\}(p)$ . That is, if  $a$  and  $b$  support exactly reciprocal outcomes, then the outcome is the same across both systems *for either ordering of  $a$  and  $b$ .*

#### 4.4 Conclusion

Serial order and rank order may be compared due to a systematic analogy between rules and constraints. Serial order and rank order correlate in their form and their effects in the particular case of processes with exactly reciprocal outcomes.

Outside the confines of this particular case, each of the two kinds of system offers different effects that are not replicable in the other. On the one hand, *overapplication* is an effect of rule interaction that cannot be replicated in constraint interaction (4.2.2), but on the other hand, *mutual interdependence* is an effect that can be handled as a constraint interaction but fails as a rule interaction (4.2.3). Pairs of processes with sub-reciprocal outcomes – in particular, syncope and epenthesis – produce *default* effects, behaving as rank order would predict, not serial order (4.3.2). Neither the system of rule interaction nor the system of constraint interaction is sufficient to derive all these effects – overapplication, mutual interdependence, and default – suggesting that some new integration of the two systems is needed to create a more descriptively adequate theory. We will attempt this in chapter 6.

The formal comparison was built on the insight that rule interaction types and constraint interaction types may be fully generalised by reference to the nature of rules and constraints as mathematical relations in the set of representations. This provides a fullness of generality which is not achieved by schematised versions of context-sensitive string-rewriting rules,  $A \rightarrow B/X\_Y$  and the like, that persist in general discussion of phonological rules (despite the well-argued theoretical progression in phonology from strings to multi-tiered graphs for phonological representation). A second essential formal insight was the recognition that rule interaction may involve feeding and overapplication simultaneously. This is easily overlooked under the received view of rule interaction that distinguishes feeding, bleeding, counterfeeding and counterbleeding (Kiparsky 1968).

5:

## DERIVATIONAL SEQUENCES AND HARMONY SCALES

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Derivational sequences and harmony scales are collections of relationships between phonological structures that are used to pick out a grammatical surface representation: a surface representation is the final form in a sequence in derivational phonology; it is the optimal form on a scale of relative harmony in optimality phonology. The two approaches would match still further if traversing along the steps of a derivational sequence to the end were consistent with traversing through increments in harmony up to the peak.

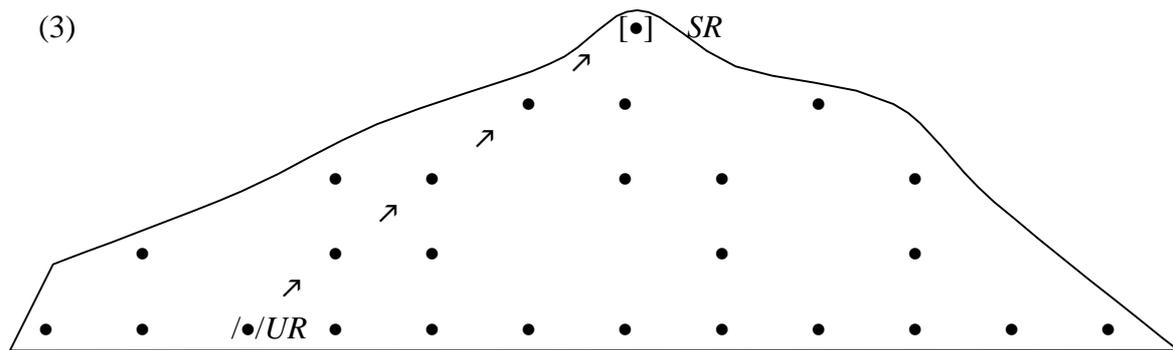
We formulate this possible analogy between derivation and harmony in 5.1, and analyse the extent to which it holds in 5.2. In 5.3, we show that derivational steps which contradict harmony are ruled out by adding a strict economy condition on derivation length. However, this is too strong, ruling out other derivations for which there is evidence in Slavic languages, which do not contradict harmony. In an appendix, we examine how to foreclose the possibility of harmony scales with multiple optimal members, since sequences do not have multiple endpoints.

### 5.1 The Derivation-Harmony Analogy

#### 5.1.1 *Paths and Landscapes*

It is noteworthy that in both derivational and optimality phonology, the relation between an underlying form and its surface form is mediated by some wider system of relations between representational structures. In the derivational framework, a sequence of representations is constructed starting from the underlying representation. The surface form is the final form of the sequence constructed. This is illustrated in (1). Representations are shown as a collection of •'s residing in some space, and a derivation is a path through that space, from representation to





This presents us with an analogy between **succession** through the derivational sequence and **incrementation** up the harmony scale, and suggests the conjecture that a derivation  $P_1 \rightarrow P_2 \rightarrow \dots \rightarrow P_{n-1} \rightarrow P_n$  be matched by the harmonies  $P_1 \prec P_2 \prec \dots \prec P_{n-1} \prec P_n$  in a corresponding harmony evaluation.

Note that (3) is a comparison across *two* theories. Some have considered putting together derivation and harmony within a single theory: "a rule *applies* if and only if its effect is to *increase* the well-formedness of the representation" (Goldsmith 1995:7 my italics, cf. Sommerstein 1974, Goldsmith 1990:318ff, 1993). It is true that the comparison we are undertaking bears an anatomical similarity with such theories of "harmonic rule application", but in theory *comparison*, we have derivation and harmony as devices belonging to two separate theories, and we are testing an apparent similarity between those theories. Thus, our construal of a derivational path 'rising' through a landscape resides in a *metatheoretical* frame, articulating a possible correspondence *across* theories. As far as we are concerned here, the fact that other phonologists have thought to place derivation and harmony alongside one another only lends additional support to the venture. In the next two sections, we undergird the analogy formally.

### 5.1.2 Structures and Candidates

In order for the analogy to make sense in formal terms, we must take care over the

harmony relation. Strictly speaking, harmony discriminates between *candidates*, and it was shown in 2.3 that the candidates evaluated are not merely structures, but include a correspondence relation to the input structure. In this they differ from the members of a derivational sequence, which are structures. However, it is possible to resolve this difference.

To think of harmony as a relation between structures is a simplificatory move which is often useful because Markedness constraints - including ONSET, NOCOMPLEX, etc. - are constraints whose evaluation of the candidate focusses entirely on the potential output structure itself. Faithfulness constraints, however, do not focus entirely on the output structure, but evaluate the whole input-output relation. Thus in the tableau (4) below, input/output constraint MAX discriminates between candidates that share output *.ba.* if differing numbers of input elements have correspondents in the output, and similarly between candidates that share *.a.*, while the output constraint ONSET evaluates all instances of *.ba.* identically, and all instances of *.a.* identically, though it does discriminate between different outputs *.ba.* and *.a.* .

(4)

/b <sub>1</sub> a <sub>2</sub> /	ONSET	MAX
.b <sub>1</sub> a <sub>2</sub> .		
.b a <sub>2</sub> .		*
.a <sub>2</sub> .	*	*
.a .	*	**

It is possible to think of markedness constraints as discriminating among structures themselves, *.ba.*, *.a.* etc., as well as the candidates in which they are contained. This leads to the property of **Harmonic Ascent** (Moreton 1999): the optimal output structure is either equal to the input structure or is a more unmarked structure than the input structure when assessed against the sub-

hierarchy of markedness constraints. For example, in (4), *.a.* is not a viable output from *.ba.*, being *more* marked than *.ba.* itself. One way of abstracting away from the evaluation of the correspondence relation by Faithfulness constraints is to exclude from consideration all but the "best" correspondence for each structure. In tableau (4), for example, *.b a<sub>2</sub>.* and *.a .* have gratuitous MAX violations, but *.b<sub>1</sub>a<sub>2</sub>.* and *.a<sub>2</sub>.* do not, so are more natural. We use this notion here. For each structure we can choose whichever correspondence relation leads to greatest harmony according to the constraint hierarchy. Call this correspondence the **most harmonic correspondence**. For example, such possibilities as gratuitous lack of correspondents for some structural elements in the input and output, or gratuitous multiple correspondents for some elements in the input and output, are excluded because they lead to excessive violations of Faithfulness constraints. We now have the notion of **structure harmony** in (5):

(5) **Relative Harmony of Structures**

Let *I* be an input form, *O1, O2* some structures.

Let *C1* be the correspondence relation  $C1 \subseteq O1 \times I$  such that

$\forall C \subseteq O1 \times I, \langle I, O1, C1 \rangle \succ \langle I, O1, C \rangle$ . Define *C2* similarly.

$\prec^{(\text{structure})}$  is defined as an ordering on structures such that

$O1 \prec^{(\text{structure})} O2$  iff  $\langle I, O1, C1 \rangle \prec \langle I, O2, C2 \rangle$

*One structure O1 is less harmonic than another O2 if and only if the candidate containing O1 under the most harmonic correspondence is less harmonic than the candidate containing O2 under the most harmonic correspondence.*

### 5.1.3 Formulating The Analogy

Now that a notion of relative harmony of structures has been properly derived from the harmony relation on candidates, the derivation/harmony analogy may now be expressed as in (6):

(6) **Derivation / Harmony Analogy**

Let  $D=P_1, \dots, P_n$  be a derivation.

Let  $H$  be a harmony scale in which  $P_n$  is optimal

$D$  and  $H$  are analogous to the extent that, for  $i=1, \dots, n-1$ :

if  $P_i$  is succeeded by  $P_{i+1}$ , then also  $P_i$  is less harmonic than  $P_{i+1}$

Of course, harmony relationships exist between many more pairs of structures than just those which also happen to be in the derivation, so the analogy between  $D$  and  $H$  is tested just for those specific structures that are in  $D$ , seeing whether the succession relationships will be matched by harmony relationships.

A formally more thorough-going analogy can be achieved if we take into account the analogy between input-output correspondences and derivational-history relations which specify how structures in a derivation correspond with the original structure (chapter 3). The fuller analogy in (7) obtains between derivational sequences and harmony scales where the modifications to the underlying structure are the same for structures in the derivational sequence and in the harmony scale, i.e. that derivational histories are always equal to the most harmonic correspondence relations.

(7) **Derivation / Harmony Analogy (advanced)**

Let  $D=P_1, \dots, P_n$  be a derivation; for each  $i$ , let  ${}_1H_i$  be the derivational history relation for  $P_i$  in the derivation.

Let  $H$  be a harmony scale in which  $P_n$  is optimal; let  $C_i$  be the most harmonic correspondence between input and the possible output  $P_i$ , for each  $i$ .

$D$  and  $H$  are analogous to the extent that, for  $i=1, \dots, n-1$ :

(i)  ${}_1H_i = C_i$  ; (ii) if  $P_i$  is succeeded by  $P_{i+1}$ , then also  $P_i$  is less harmonic than  $P_{i+1}$

A Duke of York gambit of deleting and re-inserting an element, for example, would always fail condition (7i) of this more thorough-going analogy since the equivalent MAX and DEP violations could never be the most harmonic correspondence (faithfully mapping the element is better). In typical cases (7i) is a reasonable demand, for, as shown in 3.3, derivational histories and input-output correspondences take the same intuitively natural forms to the extent that violated Faithfulness constraints are ranked as low as possible ("Constraint violation is minimal") and derivations are as short as possible (Economy of derivation), except perhaps in a few formally subtle cases.

## 5.2 The Extent of the Correlation

Having formulated the analogy between derivational succession and harmony incrementation in a formally defensible way, we now test the actual extent to which traversing along the steps of a derivational sequence to the end is consistent with traversing through increments in harmony up to the peak.

Moreton (1999) has proven the key property of Harmonic Ascent for constraint evaluation systems, according to which the output form given by a hierarchy of Markedness and Faithfulness constraints is either identical to the input or more harmonic than the input – as a

result of satisfying high-ranking Markedness constraints. As far as comparison with derivations is concerned, this means that:

- if the output is identical to the input, then the analogous derivation is one with no steps at all, so the derivation-harmony correlation is vacuous;
- if the output is different and therefore more harmonic than the input, it follows that a derivation which takes a path from one to the other corresponds to an *overall* increase in harmony, ending on a more harmonic form than the one it starts on.

The question now is whether or not this increase is distributed over each one of the individual steps of the derivation.

### 5.2.1 Last Step as Increment

Whenever a derivational sequence and a harmony scale converge on the same surface form, the following result in (8) obtains: the last step in the derivational sequence always corresponds to a harmony increment, since the final form is also the optimal one on the harmony scale, whereas the penultimate form in the sequence is suboptimal on the harmony scale.

#### (8) Last Step as Only Necessary Increment

Let  $D=P_1, \dots, P_n$ , be a derivation; let  $H$  be a corresponding harmony scale converging on the same surface form as  $D$ .

a. *In the derivation, each structure except the last is immediately succeeded by another.*

$$\text{for } i=1, \dots, n-1 \quad P_i \rightarrow P_{i+1}$$

b. *Each structure that happens to take part in the derivation apart from the last is suboptimal on the harmony scale.*

Assuming that  $D$  and  $H$  converge on the same surface form ( $P_n$ ), then

$$\text{for } i=1, \dots, n-1 \quad P_i \prec P_n$$



Such mismatches do indeed occur. This is illustrated from a simple example due to Prince and Smolensky (1993:206-207). Consider a rudimentary grammar which admits CV(C) syllables, and which delivers epenthesised forms for aberrant input sequences failing to comply with CV(C). Thus, given the input /V/, the grammar will derive a syllable consisting of the V augmented with an epenthetic consonant to provide the necessary onset: .cV. . A rule-based system might achieve this by a syllable formation rule and an onset-consonant epenthesis rule, but an alternative OT grammar would have constraints ONSET (syllables have onsets), NOCOMPLEX (each syllable subconstituent contains just one segment), and PARSE (segments must be parsed into syllable structure). These constraints are undominated, but FILL (constituents must be filled by underlying material) is crucially ranked below them so that epenthetic positions may be admitted so as to comply with the requirements of syllable structure. The following table (10) cites the rule applications deriving .cV. from .V. from V (entered to the left of the forms) opposite the constraint violations of the same forms given by the OT grammar (to the right of the forms), presenting a “history” of constraint violations for structures that are found in the derivational sequence.

(10) **Constraint Violation History** (Prince and Smolensky 1993:207)

Stage	Rule	Representation	ONSET	PARSE	FILL
1		V		*	
2	Nucleus Formation	.V.	*		
3	Onset Epenthesis	.cV.			*

As anticipated, the last step corresponds to a harmony increment. The last step is .V.→.cV. and

.cV. is more harmonic, by satisfaction of ONSET at the expense only of FILL. However, the previous step  $V \rightarrow .V$ . does not correspond to a harmony increment, since each registers one violation from an undominated constraint. Hence, a move from stage 1 to stage 2 along the derivational sequence constitutes a harmony plateau.

We could, of course, remedy this artificially by ranking the constraints arbitrarily. We could rank PARSE above ONSET, so that the ONSET-violating form .V. is more harmonic than the PARSE-violating form /V/ (though still not better than .cV.). Equally, however, we could rank the other way - ONSET above PARSE - so that the relation between stages 1 and 2 corresponds to a drop in harmony (though the relation between stages 2 and 3 still necessarily corresponds to a rise in harmony). In this case, then, the succession from stage 1 to stage 2 is *ambivalent* to harmony.

### 5.2.2 *Postconditions and Restraints*

We can further the analysis by considering the general properties of constraints that would be relevant to the two structures involved in a derivational step. A derivation is made up of steps containing two minimally-different representations, one of which is subject to the application of a rule and the other of which is the result of applying the rule. In an evaluation, representations are partitioned by each constraint according to how many violations they incur. So whether a derivational step corresponds to harmony incrementation or not depends on whether the constraint violations accruing to the second of the two structures are fewer, or belong to lower-ranked constraints, than those of the first.

Harnessing terminology due to Prince and Smolensky (1993:206), a constraint according to which the succeeding structure is more harmonic than the structure it succeeds we may call a **postcondition**, and a constraint according to which the succeeding structure is less harmonic than the structure it succeeds we may call a **restraint**, as in (11). A recurrent

postcondition/restraint contrast is between a markedness constraint demanding some change to the representation versus a faithfulness constraint disfavouring the change, though the concept is general enough to take in other contrasts (the postcondition/restraint “contrast” may constitute a constraint *conflict* - but not necessarily, as we will show).

- (11) rule
- $$P_1 \rightarrow P_2 \rightarrow \dots \rightarrow P_i \rightarrow P_{i+1} \dots \rightarrow P_n$$
- \*     √     ‘postcondition’
- √     \*     ‘restraint’
- discriminating constraints

A constraint may express generalisations of a subtlety different from the rule to which it is a postcondition, or restraint. The requirement that syllables have onsets represents a postcondition to the rule of onset formation. Yet, while the representation resulting from onset formation on a <C>.V.<C>.V.<C>.V. string produces .CV.CV.CV with no ONSET violations, exhaustive application of onset formation on .V.<CC>.V.V.<C>V gives .V<C>.CV.V.CV. which has fewer ONSET violations but still retains some. The difference arises because the ONSET constraint is a constraint on syllables whereas the onset formation rule is a rule about phonemes. As Roca (1994:145) observes, the principle of disallowing onsetless syllables is only satisfied by onset formation in the presence of suitable segmental material. In fact, many constraints formulated in Optimality Theory either require or are predicated over syllable structure and higher prosodic and metrical structure. Postconditions and restraints thus make more sense if applied to the *syllabification* - or for that matter, *prosodification* - of the output of each rule. This accords with the proposal in rule-based theory that syllabification re-applies to the output of each rule throughout the derivation (McCarthy 1979, Itô 1986). If we assume this, then each step  $P_i, P_{i+1}$

in the sequence itself contains a mini-sequence containing the application of some rule plus rules assigning prosodic structures.

It is clear from the diagram (11) that postconditions are consistent with the analogy between derivational succession and harmony incrementation, while restraints are directly contrary to it. But the most highly ranked constraint is always decisive in optimality theory. So the analogy will hold to the extent that for each pair of representations  $P_i, P_{i+1}$  there is some postcondition that dominates all restraints. Now constraint ranking is settled by discriminating between the optimal form and every other form, as in (12). Only at the last step will it always be the case that a postcondition dominates. Postcondition/restraint analysis thus recapitulates the result of the previous section 5.2.1.

### (12) Dominant Postcondition for Last Step

*Constraint Ranking Logic:*

If  $P_{opt}$  is the surface form and  $P_{subopt}$  another form, then there must be a constraint  $C$  which rejects  $P_{subopt}$  in favour of  $P_{opt}$ , which dominates all constraints  $C_x$  which reject  $P_{opt}$  in favour of  $P_{subopt}$ .

(Without  $C$ ,  $P_{opt}$  will not be optimal.)

$C$	$\gg$	$C_x$
$P_{opt}$		*
$P_{subopt}$	*	

*Corollary 1:* Among those forms involved in a derivational sequence  $P_1, \dots, P_n$ , where  $P_n$  is the surface form, then for  $i=1$  to  $n-1$ , there must be a constraint  $C_i$  which rejects  $P_i$  in favour of  $P_n$ , which dominates all constraints  $C_x$  which reject  $P_n$  in favour of  $P_i$ .

*Corollary 2:* There must be a postcondition which rejects  $P_{n-1}$  in favour of  $P_n$ , which dominates all restraints which reject  $P_n$  in favour of  $P_{n-1}$ . (From corollary 1, with  $i=n-1$ )

### 5.2.3 Typical Derivational Sequences

When we consider postconditions and restraints at *any* step in a derivational sequence, not just the first, there are two kinds of histories that postconditions may have. The first, represented in (13a), is where a postcondition is violated throughout an initial portion of the forms in the sequence  $P_1, \dots, P_i$ , but satisfied by the remainder. The second, represented in (13b), is where a postcondition is satisfied by forms in an initial portion, but violated by a further form or forms, and satisfied by the remainder:

#### (13) Unfed rules and Fed rules

a.	$P_1 \rightarrow P_2 \rightarrow \dots \rightarrow P_i \rightarrow P_{i+1} \dots \rightarrow P_n$	
	*      *              *      ✓              ✓	‘postcondition:i+1’
	✓      ✓              ✓      *              *	‘restraint:i+1’
b.	$P_1 \rightarrow \dots \rightarrow P_i \rightarrow P_{i+1} \rightarrow P_{i+2} \dots \rightarrow P_n$	
	*                      *      ✓      ✓                      ✓	‘postcondition:i+1’
	✓                      ✓      *      ✓                      ✓	‘postcondition:i+2’
	✓                      ✓      ✓      *                      *	‘restraint:i+2’

Whereas (13a) reflects a rule whose structural description is met at the outset of a derivation, (13b) reflects a rule whose structural description is fed by another rule in the derivation. In (13a), succession corresponds to harmony incrementation, since a postcondition must dominate all restraints by comparing their violations for  $P_i$  and  $P_n$ , shown in (14a):

(14) **Ranking Arguments**

## a. No feeding interaction in derivation

	postcondition:i+1	>>	restraint:i+1
P <sub>i</sub>	*		✓
P <sub>n</sub>	✓		*

## b. Feeding interaction in derivation

	postcondition:i+1	>>	restraint:i+2
P <sub>i</sub>	*		✓
P <sub>n</sub>	✓		*

	postcondition:i+2	>>	restraint:i+2
P <sub>i+1</sub>	*		✓
P <sub>n</sub>	✓		*

For the feeding interaction, however, no ranking argument can be formulated between the two postconditions because they do not actually conflict: both are equally satisfied by the optimal form. This despite the fact that at the step (i,i+1), one (postcondition-1) is a postcondition and one (postcondition-2) is a restraint. The only ranking arguments that can be made are between these constraints and constraints which are violated by the surface form, as given in (14b). This includes the application of a “repair”-rule to the output of another rule, which is one use of the feeding interaction in rule theories. So, as Prince and Smolensky (1993:205ff) observe, the postcondition of the rule whose output is to be “repaired” (e.g. nucleus formation for a ‘V’) and the postcondition of the repair rule (e.g. onset epenthesis) do not conflict, since both are satisfied in the surface form.

It is also possible that a derivation may fail to converge on the harmony peak determined

by the constraints which act as postconditions and restraints on the derivational steps. The path may overshoot or undershoot. Overshoot describes a case where there are more disparities between the final form in the derivation and the underlying form than between the optimal form and the underlying form, and undershoot describes a case where there are fewer disparities between the final form in the derivation and the underlying form than between the optimal form and the underlying form. These possibilities stand outside the assumption made in 5.2.1 that the derivational sequence and the harmony scale converge on the same surface form, but if we relax this assumption and examine the postconditions and restraints at each step of overshooting and undershooting derivations, we find in (15) that counterbleeding derivations positively correlate with the harmony scale, even though the path circumnavigates the most harmonic form and fails to converge on it.

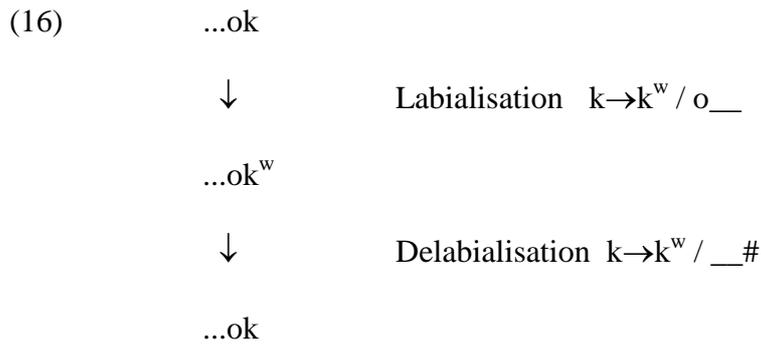
(15) **Undershoot and Overshoot**

a.	Undershoot: counterfeeding	(feeding alternative)	
	$P1 \rightarrow P2$	$P1 \rightarrow P2 \rightarrow P3$	
	*     ✓	*     ✓     ✓	‘postcondition-2’
	✓     *	✓     *     ✓	‘postcondition-3’
	$P1 \approx P2 (< P3)$	$P1 \approx P2 < P3$	
b.	Overshoot: counterbleeding	(bleeding alternative)	
	$P1 \rightarrow P2 \rightarrow P3$	$P1 \rightarrow P2'$	
	*     ✓     ✓	*     ✓	‘postcondition-2’
	*     *     ✓	*     ✓	‘postcondition-3’
	$P1 < P2 < P3 (< P2')$	$P1 < P2'$	

In a counterfeeding interaction (15a), just as one rule applies but the other fails to apply afterwards, so also one postcondition is alleviated while another postcondition is left violated. By contrast, when one rule feeds the other, both postconditions are satisfied. In a counterbleeding interaction, portrayed in (15b), two constraint violations are alleviated over two steps, both matching with harmony increments. Although the counterbleeding derivation is consistent with harmony incrementation it does not lead to the harmony *maximum*, but rather skirts it. The output obtained by the bleeding derivation (P2') will be more harmonic than the end-point of the counterbleeding derivation (P3), because when one rule bleeds the other, removing the need for it to apply, both constraints are alleviated in one step, a more faithful alternative. Overshoot and undershoot offer a mixture of advantages and disadvantages empirically (see chapter four and chapter six): overshooting derivations provide the correct results in “overapplication”, but precisely the wrong results in cases of “default” effects; undershooting derivations fail to derive “mutual interdependence” effects, though they allow “underapplication” effects to be described.

#### 5.2.4 A Duke-of-York Derivation: Irreducible Harmony Drop

At steps caused by rules which feed, where there is no conflict between postconditions and restraints, there is no basis for a derivational step which *necessarily* leads to a *less* harmonic form. It remains to ask whether there are any such cases among derivational sequences and harmony scales which converge on the same surface form. This possibility is found in Duke-of-York derivations. In the Duke of York Gambit, some structural change  $A \rightarrow B$  is followed in the derivation by the reverse change  $B \rightarrow A$ . An illustrative example in (16) is from Nootka (Pullum 1976:94, from an unpublished paper by Campbell).



Nootka has labialised and unlabialised dorsal stops. Labialisation is always removed word-finally, but dorsal stops are always labialised following an *o*. But in the overlapping context  $o\_ \#$  dorsal stops are not labialised, so Delabialisation must be ordered after Labialisation to ensure this. Then, given an underlying form ending in  $\dots ok\#$ , both rules apply in turn to leave the stop unlabialised at the end.

On a harmony scale, the form  $\dots ok$  will be optimal, and hence more harmonic than  $\dots ok^w$ . This is supported by the following tableau:

(17)

$/\dots ok/, / \dots ok^w/$	No final $k^w$	No $k$ after $o$
☞ $\dots ok$		*
$\dots ok^w$	*!	

As ever, the final step of the derivational sequence  $\langle \dots ok^w, \dots ok \rangle$  corresponds to a harmony increment, but since the preceding step  $\langle \dots ok, \dots ok^w \rangle$  is the inverse of the last step, it inevitably corresponds to a harmony drop.

In general, a derivational step leads to a less harmonic form whenever there is some restraint that dominates all postconditions at that step. Assuming that the derivational sequence

and harmony scale converge on the same output, this happens when the surface form  $P_n$  violates one of the postconditions, so that some restraint must dominate that postcondition to guarantee the optimality of  $P_n$ .

(18) **Harmony Drop**

a.	$P_1 \rightarrow \dots \rightarrow P_i \rightarrow P_{i+1} \dots \rightarrow P_n$					
		*	✓		*	‘postcondition’
		✓	*		✓	‘restraint’
b.						
	restraint >> postcondition					
	$P_{i+1}$	*	✓			
	$P_n$	✓	*			

This means, as the derivation (18a) illustrates, that if there is a derivational step corresponding to a drop in harmony, it must be that the remainder of the derivation contains changes that reverse the effect at that step. A Duke of York gambit does this.

5.2.5 *Summary*

Unlike the other derivational patterns we have examined, a simple Duke of York gambit involves a step that necessarily contradicts harmony. Feeding interactions involve a step that is ambivalent to harmony, depending exactly on how the constraints are (arbitrarily) ranked. Other derivations – even derivations that overshoot the result given by the constraints that are postconditions and restraints for the steps of the derivation – correspond to increments in harmony.

### 5.3 Restricting Sequences

In 5.2.4, it was shown that where a step corresponds to a harmony drop, the change at that step is reversed later in the derivation. If we excluded derivations with such reversals we would eliminate all derivational steps that correspond to a harmony drop, achieving a closer match between derivation and harmony. We begin by considering a ban on Duke-of-York derivations, but the derivation-harmony mismatch goes deeper: we soon show that sequences themselves are mathematically different from scales.

#### 5.3.1 *Excluding Duke-of-York Derivations*

Pullum (1976) observed that generative phonologists have often expressed misgivings, somewhat inchoately, about Duke-of-York derivations and attempted to avoid them. Reviewing this phenomenon in chapter three, we argued that Duke-of-York derivations are unexplanatory and generally unsupported empirically. They fail to explain the similarity of surface forms to their underlying forms, and in crucial cases of languages with both vowel deletion and insertion, where deletion-insertion derivations would be detectable by impoverishment of the vowel inventory, they fail to occur.

Excluding Duke-of-York derivations would eliminate a class of derivations which have a step that goes down the harmony scale instead of up. And it would force us to re-analyse putative cases - labialisation in Nootka (5.2.3.) need not apply word-finally where it would be reversed if it is confined to dorsals in syllable onset, or to prevocalic dorsals whose release phase is more amenable to carrying labialisation audibly. However, as well as excluding some Duke-of-York gambits that do *not* have a step that goes down the harmony scale (see 5.3.3 below), the move would fail to exclude other derivational sequences that do. In simple Duke-of-York derivations, a structure is repeated in two steps when one structural change is immediately reversed by the opposite change, but a structure could conceivably be repeated under different conditions, as the

hypothetical derivations in (19) demonstrate.

(19)

- a.    pai  
       pii         Raising *a*  
       pi:         Vowel Deletion in presence of identical vowel  
       pai         Diphthongisation
- b.    prar  
       parr         Liquid/Vowel Metathesis  
       parar        *a*-Epenthesis  
       prar         Vowel Deletion between Stop and Liquid

Neither of the hypothetical derivations in (19) employs a Duke-of-York gambit. The first ends in a fissure of one vowel into two, re-creating a diphthong of which one half was deleted. The second has contrary structural changes, insertion and deletion of *a*, but these apply in different positions and a third rule, a metathesis, completes the re-creation of a previous structure. A structure might be repeated by some even more convoluted set of changes. Excluding Duke-of-York derivations only deals with the more obvious cases.

Yet all sequences that have a repeated member, Duke of York gambit or not, necessarily contain a step which corresponds to a drop in harmony, conforming to the scheme given in (18). In the harmony evaluation corresponding to the derivation *prar* → *parr* → *parar* → *prar* (19b), the constraint requiring metathesis of *a* and *r* (a postcondition at the first step) is violated by the final form, so must be dominated by a conflicting constraint that is satisfied in the final form. The constraint requiring metathesis is violated when it would create *rr*, so is dominated by a

constraint against  $rr$ . Then the step  $prar \rightarrow parr$  is a drop in harmony because it creates  $rr$ . For all repetition after two or more steps, the situation is as in (20) (illustrated for repetition after three steps for concreteness):

(20) **Structure Repeated in Sequence**

$P_1$	$\rightarrow$	...	$\rightarrow$	$P_i$	$\rightarrow$	$P_{i+1}$	$\rightarrow$	$P_{i+2}$	$\rightarrow$	$P_i$	...	$\rightarrow$	$P_n$	
				*		✓		✓		*			*	postcondition:i+1
				✓		*		✓		✓			✓	postcondition:i+2
				✓		✓		*		✓			✓	postcondition:i+3

At the step which moves away from the structure which is eventually repeated, any postcondition is eventually violated again. Assuming the rule which changes the repeated structure does not apply second time round (nor does any other rule change any part of its structural description, which would create an overshoot), then the constraint violation will persist among subsequent members of the sequence, including the final surface form. This leads to a ranking argument: some other conflicting constraint must be satisfied at the expense of postcondition:i+1. A postcondition at the second step after the structure to be repeated is such a constraint, being both a restraint at the first step and satisfied by the surface form.

(21) **Ranking Argument** for (20)

		postcondition:i+2	>>	postcondition:i+1
$P_{i+1}$	*			✓
$P_n$	✓			*

This takes care of repetition after two or more steps. Repeating a structure in one step can

only happen with a rule capable of producing an output identical to its input. Out of the usual set of operations (see 3.1), the only possibility is a rule of metathesis that sometimes interchanges identical elements, e.g.  $pr_i ar_j \rightarrow pr_j ar_i$ . This would correspond to a drop in harmony since the input and output would violate constraints identically except that the output has an additional violation of a faithfulness constraint (LINEARITY, in the case of metathesis; and if it happened twice in a derivation, the second time would correct the LINEARITY violation but the first time would still correspond to a harmony drop).

### 5.3.2 Sequences are not Ordered Sets

It is possible for a sequence to contain a member that is repeated in the sequence, but this does not happen in harmony scales, for each entity in a scale has its own place in the scale. This sets sequences apart from scales mathematically.

An *ordering* is a relation that is irreflexive, asymmetric and transitive, whose definitions are given below:

(22) Let A be a set. Let R be an ordering relation in A. The following are true of R:

a. **Irreflexivity:**  $\forall a \in A$ , it is not the case that  $aRa$ .

*No element is ordered before itself.*

b. **Asymmetry:**  $\forall a_1, a_2 \in A$ , if  $a_1 Ra_2$  then it is not the case that  $a_2 Ra_1$ .

*A pair of elements can only be ordered one way.*

c. **Transitivity:**  $\forall a_1, a_2, a_3 \in A$ , if  $a_1 Ra_2$  and  $a_2 Ra_3$  then  $a_1 Ra_3$ .

*The order of two elements is settled if there is an intermediary ordered between.*

The relation “less harmonic than” is an ordering: (a) no representation is less harmonic than itself (irreflexivity), since it only has one set of constraint violations; (b) one representation cannot be

both less harmonic and more harmonic than another (asymmetry), since the highest-ranked constraint on which they differ settles one way or the other; (c) if one representation is less harmonic than another, it is less harmonic than representations that the other is less harmonic than (transitivity), because the one representation has more serious violations than the other, and these are more serious than still less costly representations.<sup>51</sup>

It would likewise seem initially plausible to suggest that derivational sequences are ordered sets, albeit smaller, finite ones. One can recognise on sequences a relation of immediate succession e.g. ‘P2 immediately succeeds P1’ and from it a general relation of succession e.g. ‘P5 succeeds P1’. These properties fail, however, in sequences that have a repeated member, because a repeated member of the sequence succeeds itself. For example, in two steps a Duke-of-York gambit gives  $A \rightarrow B \rightarrow A$  giving rise to the relations for each step ‘B succeeds A’ and ‘A succeeds B’ (failing asymmetry) and then overall ‘A succeeds A’ (failing irreflexivity). This shows that sequences are not the same as ordered sets.

Sequences still make formal sense even if they are not ordered sets. Members of a sequence have a “place” in the sequence; repetition is when a member of the sequence has more than one place in the sequence. The places in the sequence are ordered, even if the members are not. It is often convenient to think of the “places” as numbers - as we do when we cite a derivational sequence as  $P_1, P_2, P_3, \dots, P_n$ . This leads us to a definition of sequences, as given in (23).

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<sup>51</sup> Other essential properties of the “less harmonic than” relation include that: (i) it has a *greatest* element (there is at least one optimal element); (ii) it defines a *partition* into *equivalence classes*, whose members are characterised by the same degree of violation and which share the same ordering relations to members of the other classes; (iii) it is not *connected*, since there are pairs of structures that are not ordered by harmony one way or the other (i.e. any pair in the same equivalence class).

(23) **Definition: Sequences**

a. A **sequence** is a triple  $\langle M, P, A \rangle$  where  $M$  is a set of **members**,  $P$  is a set of **places**, which is well-ordered with a least element (*e.g., the set of natural numbers*), and  $A$  is a function from  $P$  onto  $M$ .

*Each place in a sequence starting from the first is assigned a member.*

b. A sequence is **ordered** if  $A$  is a one-to-one correspondence.

*If each member of the sequence occurs only once, members will be ordered incidentally along with their respective places.*

c. A sequence is **finite** if the domain of  $A$  in  $P$  is finite.

*If only a finite number of places are assigned members, the sequence terminates.*

In a derivational sequence where there is no repeated member, the members and places are then in one-to-one correspondence, so that particular derivation at least is ordered. Derivational sequences are always finite, because they terminate after a finite number of places (i.e. stages), although derivations are not bounded by any particular limit (e.g. “10”, or “99”). The finiteness of derivations is significant in connection with derivations that contain a repeated member, for it means that rules cannot re-create a structure again and again indefinitely. Unconstrained re-application of rules must be prevented either by strict ordering or by the constraint that rules cannot apply in interrupted sequence (Ringen 1976), and by the regularity constraint that rules cannot re-apply to the new configuration in their own output (Johnson 1972, Karttunen 1993).

We return to the differences between sequences and scales in an appendix to this chapter. For while sequences exceed the orderedness of scales in general, scales exceed the connectedness of sequences in general.

### 5.3.3 Derivational Economy

Following (23b), derivational sequences with repeated members may be excluded directly by the condition of orderability given in (24a), which admits only sequences whose members have just one place in the sequence. Alternatively, the economy condition (24b) which minimises the length of derivations, also excludes these sequences. Economy of derivation has been explored as a principle of Minimalist linguistic theory (Chomsky 1995, Calabrese 1995).

#### (24) Conditions that exclude sequences with repeated members

- a. **Orderability:** Derivational sequences are ordered.
- b. **Economy:** Derivational sequences are of the minimum length possible to derive their final member from their initial member.

If a structure is repeated in a derivation,  $P_1, \dots, P_i, \dots, P_i, \dots, P_n$ , then the derivation is replaceable with a shorter one which lacks the portion of the sequence  $P_i, \dots, P_i$  that comes between the repeated tokens. This excludes not only Duke-of-York gambits (which exceed the minimum length possible by precisely two steps), but any other collection of rules which re-create a structure found earlier in the sequence. In fact, the economy condition is stronger than the orderability condition. The economy condition, but not the orderability condition, would select the derivation in (25b) over the one in (25a):

- (25) a.     \*{wati → wari → war → wat}
- b.     wati → wat

In the eliminated derivation (25a), the final step re-creates a /t/ removed at an earlier step. There is no repeated structure, but it is not the shortest possible derivation. The economy condition also

inveighs against some other derivations (e.g.  $\emptyset \rightarrow +F \rightarrow -F$  exceeds the shorter  $\emptyset \rightarrow -F$ ).

Duke-of-York derivations, and derivations in which a structure is repeated, typify a certain family of derivations. There is some configuration within a structure that is altered and subsequently reconstructed (by Duke-of-York gambit, or some other way) in the course of a derivation (possibly with other rules making other changes). This is always technically uneconomical. Furthermore, derivational steps that necessarily correspond to a harmony drop always fall within this family: for as found in 5.2.3, any derivational step that necessarily corresponds to a harmony drop must be reversed in a subsequent part of the sequence (assuming that the sequence converges to the same surface form as the harmony scale). Since the economy condition (24b) excludes this family, it follows that it also eliminates all derivations that necessarily contradict harmony (feeding interactions can be made to contradict harmony by an arbitrary ranking of the constraints, but do not *necessarily* contradict harmony). This gives us (26):

(26) **Derivation/Harmony Correlation under Derivational Economy**

Economical derivations that converge to the same output as a harmony scale do not flatly contradict the harmony scale at any step.

The condition that derivations and harmony scales converge to the same output makes this a very basic kernel of patterns, of course, excluding overshoot and undershoot but including bleeding and feeding effects (as shown in 5.2.3), and mutually-contrary processes *if* they are prevented from creating an uneconomical Duke-of-York derivation. It also excludes the more complex Duke-of-York derivations where the initial change feeds an intervening rule before the reverse change is made, which McCarthy (2003) has argued are unattested.

However, although derivational steps that necessarily correspond to a harmony drop

always fall within the family of uneconomical derivations that alter and re-construct part of a structure, there are some within this family that do not contradict harmony scales. Some Duke-of-York derivations are simply a series of feeding interactions, as Pullum (1976) discovered. He offered the following hypothetical data and rules:

(27) Pullum (1976:89-90)

káti	'wallaby'
katínlu	'wallabies'/wallaby-PL
katenlóma	'by wallabies'/wallaby-PL-ERG

- A. Penultimate vowels are stressed.
- B. High vowels become mid in unstressed, closed syllables.
- C. Final *n* deletes after mid vowels.
- D. Final mid vowels become high.

The forms can be derived as follows:

(28)

	A		B
a. /katin+lo+ma/	→	katin ló ma	→ [katenlóma]

	A		D
b. /katin+lo/	→	katín lo	→ [katínlu]

A                    B                    C                    D

c. /katin/    →    kátin    →    káten    →    káte    →    [káti]

The last derivation (28c) uses a Duke-of-York gambit in regard to the height of the second vowel. The vowel begins high, is lowered by rule B, and is then raised again by rule D. There is no repetition of any structure, because rule C intervenes between the gambit-rules B and D, so the final form is not the same as the form prior to B. Furthermore, the rules apply simply when their structural description is met, each feeding the next. It is even the case that all the rules are transparent: no rule alters the structural description of any previous rule. This Duke-of-York gambit may be replicated by a harmony evaluation:

(29) Constraints

- A    Stress is penultimate.
- B    No high vowels in unstressed, closed syllables.
- C    No word-final *n* after mid vowels.
- D    Word-final vowels are high.

/katin/	A	B	C	D	IDENT([high])	MAX(C)	
katin	*!						
kátin		*!					
káten			*!		*		
káte				*!	*	*	
☞ káti						*	

Even though the derivation (28c) does not contradict harmony as tableau (29) shows, it would be excluded by the economy condition. Of course, it is not positively consistent with harmony either. Comparison to the tableau shows that the derivational steps prior to the last correspond to harmony plateaus (unless some arbitrary ranking of the constraints is made), in accordance with the pattern for feeding interactions observed in 5.2.2. This shows that the possibility of feeding initiates open-endedly complex derivations that provide increasingly serious mismatches with harmony:

(30)

<u>Seriousness of Mismatch</u>	<u>Derivations</u>
Ambivalence to harmony	Feeding derivations – including those uneconomical derivations where the rule recreating structure changed by an earlier rule is fed by an intervening rule
Flat contradiction of harmony	All other uneconomical derivations in which structure is re-created after being altered – including all unorderable derivations.

Derivations partly similar to Pullum's example occur in the Slavic languages Slovak (Rubach 1993:267) and Polish (Rubach 1984:101), where Depalatalisation undoes the effect of Palatalisation when Depalatalisation is fed by the intervening rule of yer deletion. In Slovak, the derivation of *vodný* 'watery', adjective from *voda* 'water', runs as follows:

- (31)
- |   |           |                  |
|---|-----------|------------------|
| 1 | vod+En+ý  |                  |
| 2 | vod´+En+ý | Palatalisation   |
| 3 | vod´+n+ý  | Yer Deletion     |
| 4 | vod+n+ý   | Depalatalisation |

The latent "yer" vowel, in this case a front vowel capable of palatalising the root-final consonant, does not vocalise in this context, leaving a consonant cluster. This removes the conditioning environment for palatalisation - an overapplication effect. Because of yer deletion, the *d´* is now in the preconsonantal environment of Depalatalisation (as opposed to the prevocalic environment of Palatalisation), a feeding effect. As sketched in (32), this derivation too may be replicated on a tableau:

(32)

/vod+En+ý/	Palatal (__FrontVowel)	No Vocalisation	No Palatal (__CoronalCons)
vodený	*!	*	
vod´ený		*!	
vod´ný			*!
☞ vodný			

The Slavic pattern has in common with Pullum's hypothetical example the feature that the reversal rule is fed by an intervening rule. As tableaux (29) and (32) indicate, this corresponds to a case where constraints do not conflict since they trigger the contrary processes under disjoint conditions. This differs from examples of Duke-of-York derivations with intervening rules studied by McCarthy (2003). In the examples which McCarthy inveighs

against, the intervening rule does not feed the reversal rule, but rather the original rule feeds both the intervening rule and the reversal rule. Those cannot be replicated by constraint interaction.

The result is that Duke-of-York derivations that are consistent with harmony have empirical currency, as in Slavic Depalatalisation. Other Duke of York derivations (i.e. all those which flatly contradict harmony) are unattested, a claim supported both by the universal absence of vowel deletion-and-insertion derivations (see 3.4.4, 4.4.2), and by the arguments in McCarthy (2003) against other putative Duke-of-York derivations with intervening rules. Hence, economy of derivation is just slightly too strong a condition, and instead it is consistency with harmony that emerges as the property that matches the empirical record.

#### **5.4 Conclusion**

The analogy between derivational sequences and harmony scales has real but limited currency. The succession-incrementation correlation holds solidly for the last step of a derivation that converges with a harmony maximum, but recedes as sequences and scales themselves recede from the mathematical properties held by the other. For sequences and scales are mathematically different, as demonstrated in 5.3.2 and in the appendix to this chapter.

Some derivations (those with feeding interactions) contain a derivational step that is ambivalent to harmony; others (most Duke of York derivations) flatly contradict harmony. Derivational steps which flatly contradict harmony are eliminated by the condition of derivational economy. However, this would exclude other derivations which do not flatly contradict harmony, and hence would exclude the palatalisation patterns in Slavic languages. Whereas the economy condition is too strong, it appears that derivations which are consistent with harmony should be admissible, but derivations that contradict harmony should not.

### Appendix: Scales Are Not Connected Sets

Sequences differ mathematically from scales in that sequences are not ordered sets (5.3.2), but also in that harmony scales are not *connected sets*: constraints do not necessarily discriminate between every last pair of representations. By contrast, the property of succession differentiates between every pair of members in a sequence. Hammond (2000) points out that it is possible to construct evaluation systems that select several outputs as optimal. There could be two candidates  $a, b$  that are maximally harmonic with respect to the available constraints, and no constraint that further discriminates between  $a$  and  $b$ . Sequences intrinsically have just one final member, so always provide one unique output (caveat: assuming rules are "obligatory" rather than "optional"). We pursued our comparison of sequences and scales that have the same final/optimal output, but harmony scales are only comparable with sequences to the extent that they have a unique optimal form. This being so, we consider how to foreclose the possibility of multiple optimal forms.

Successive constraints in a hierarchy pare down the candidate set's most harmonic forms, but ending up with just one depends on "enough" of the "right" constraints. Individual phonologists can always propose constraints to get the single output they want in a particular case, but if we consider the conditions under which multiple outputs could logically arise, we can see what is required to deliver only one optimal output in general. We now show that there are two definitive possibilities for generating multiple outputs, in evaluation systems that employ markedness and faithfulness constraints.

Suppose two candidates  $a$  and  $b$  are both optimal. Either they have identical output structures under different correspondence relations, or they have different output structures - if they have identical output structures this presents no problem - they still give a unique output, however subtle and unusual this might be. Suppose instead, then, that  $a$  and  $b$  have different structures. Either (i) they have different faithfulness-constraint violations or (ii) they have the

same faithfulness violations.

Suppose first they have (i) different faithfulness violations. On (at least) one constraint F,  $b$  is less faithful than  $a$  (say). If  $b$  is still equally optimal, it must be more harmonic than  $a$  according to another constraint C ranked equally with F:

(A1)	F	C
	$a$	*
	$b$	*

In this scenario, however, the constraints F and C do at least discriminate between the possible outputs. A unique output may be obtained simply by ranking them.  $F \gg C$  selects  $a$  uniquely;  $C \gg F$  selects  $b$  uniquely. This can be resolved in one of two obvious ways. Either (i) we require that rank order of constraints is total, so we remove the possibility that two outputs can emerge from the equal ranking of two normally conflicting constraints, or (ii) we state as an added axiom the requirement that only one output be accepted, and this axiom will force constraints that favour alternative outputs to be ranked one way or the other.

Suppose next that two outputs have the same faithfulness violations - case (ii). Since  $a$  and  $b$  are different structures, there must be (at least) one faithfulness constraint that is violated at two different positions - two different disparities of the same type on the same tier.

Schematically, we can present  $a$  and  $b$  as containing the following structures, disparities of the form  $p \rightarrow q$  in contexts  $x\_y\_z$ :

(A2)	<i>input:</i>	$xpypz$
	$a:$	$xpyqz$
	$b:$	$xqypz$

If the disparity is motivated in both contexts  $x\_y$  and  $y\_z$ , why are both not carried through?: why is  $xqyqz$  not optimal? It may be that one change is enough, for example if  $p \rightarrow q$  is an insertion of an epenthetic vowel into a cluster of consonants  $CCC \rightarrow CVCC$ ,  $CCC \rightarrow CCVC$ , then one epenthesis may be enough to create an acceptable syllable structure of consonants and vowels. But if there is still motivation to instantiate a disparity  $p \rightarrow q$  in two places, there must be some dominant constraint blocking  $xqyqz$ . This could conceivably be a constraint  $*\dots q \dots q \dots$  creating a dissimilation effect, e.g. ruling out successive identical vowels or consonants. Or if the  $p \rightarrow q$  disparity is in fact one of deletion  $p \rightarrow \emptyset$ , e.g. vowel deletion  $CVCVC \rightarrow CVCC, CCVC, CCC$ , there could be limitations  $*xyz$  on the resulting strings such as unacceptable consonant clusters.

If we wish to rule out the possibility that multiple outputs arise by violation of one Faithfulness constraint at different positions, we must distinguish between  $a$  and  $b$  by constraints which distinguish different positions in a structure. Such constraints are necessary, for example to place epenthetic vowels correctly into  $CiCC$  rather than  $*CCiC$  in Yokuts (McCarthy 2002:58), recapturing what in rule theory would be achieved by indexing the structural change  $\emptyset \rightarrow i$  to the correct place in the structural description  $C\_CC$ . We might, for example, adopt a constraint which awards a violation for every segment separating a vowel from the left edge of the word. This follows the NOINTERVENING constraint family (see 2.4.2). In general, process placement can be achieved in one of two ways. Either (i) we assume that all constraints that would ever be needed to distinguish alternative sites are present in all grammars, or (ii) we state as an added axiom the requirement that only one output be accepted, and this axiom will force the construction of constraints as required that eliminate all but one output.

The available options do not explain why there would be only one output from a grammar. An axiom would be essentially stipulative. Alternatively, the necessary constraints

must be *both* already present *and* totally ranked to get the right results. Perhaps instead the maintenance of a unique output where multiple outputs would be possible is explained by functional considerations of simplicity of expression and communication. If these considerations apply loosely, we would predict that the specific kinds of variability in grammatical forms predicted by evaluation systems – both optional processes and variable placement of a process in structure – will be frequent in language variation.

**6:****CONSTRAINT CUMULATION THEORY**

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This chapter presents a new formal synthesis of derivational theory and optimality theory, **Constraint Cumulation Theory** (CCT). Phonological constraints are arranged in an order which serves both as a serial order and a rank order: earlier constraints are **pre-eminent** over later ones in that they may take effect first, then persist alongside later ones, remaining dominant over them. Phonological representations of utterances, then, are derived by constraints which *accumulate* one by one.

Our first task will be to present the system and demonstrate its descriptive coverage of the interactive effects among phonological processes recognised in chapter four: *overapplication*, *mutual interdependence*, and *default*. We also demonstrate its selective coverage of Duke-of-York interactions, which accords with the findings of chapter five.

Then, we further examine patterns of underapplication and overapplication, ultimately predicting from the theory that neutralisation and deletion processes will remain transparent except under certain conditions, whereas insertion and conditioned specification of features are expected to become opaque. This successfully resurrects a long-abandoned problem (Kenstowicz and Kisseberth 1973, 1977).

**6.1 Towards Multifarious Interaction**

An adequate theory of phonological grammar must be able to accommodate all the various interactions between generalisations witnessed in the phonology of the world's languages. This includes the ability to accommodate all the examples in (1).

(1)

a. Supporting Generalisation: Vowel Raising in non-standard Italian (Calabrese 1995)

/pret i/ → [priti] (raising of vowel supports tensing of high vowels)

\*[priti] (raised, but untensed)

b. Overapplication: Epenthesis in High-Vowel/Liquid Sequences in Eastern Massachusetts English (McCarthy 1991)

/fijɹ/ → [fi.jə] (epenthesis overapplies with respect to loss of *r*)\*[fi.jəɹ] (epenthesis, but no *r*-deletion)\*[fij] (*r*-deletion removing the need for epenthesis)

c. Mutual Interdependence: Stem-Syllable Alignment &amp; Coda Licensing

in Lardil (Prince and Smolensky 1993)

/kaŋ/ → [kaŋ.ka] (stem ends at syllable edge with nasal coda licensed)

\*[ka.ŋa] (stem and syllable misaligned)

\*[kaŋ.a] (nasal coda unlicensed)

d. Default: Vowel Syncope in Yokuts (Kisseberth 1970a)

/kili:y a ni/ → [ki.ley.ni] (one vowel omitted, CV(C) syllables maintained)

\*[ki.ley.n] (vowel omissions, unacceptable coda cluster)

\*[ki.le.yin] (vowel omissions compensated by *i*-epenthesis)

As was demonstrated formally in chapter 4, rule-based generation systems and constraint-evaluation systems are only partially successful at capturing this range of patterns. Their performance is summarised in table (2) below. In its standard conception at least, Optimality Theory cannot handle (b) *overapplication*. On the other hand, rules cannot handle (c) *mutual interdependence* at all; (d) *default* is expressible only rather awkwardly by imposing an additional "blocking" subsystem on the core rule system (see 2.2.2, 4.2.2).

(2)	Rule-based Derivational Theory	Optimality Theory
a. Supporting Generalisation	✓	✓
b. Overapplication	✓	✗
c. Mutual Interdependence	✗	✓
d. Default	✗	✓

However, by combining the strengths of both derivational theory and optimality theory in a cumulative system of constraints, all these patterns can be described.<sup>52</sup>

### 6.1.1 The Constraint Cumulation System

We propose that a phonology consists of a set of constraints on representations **M1, M2, M3, ..., Mn** ('M' for Markedness broadly construed), and that these are interspersed with Faithfulness constraints *F1, F2, F3, ..., Fm* in an ordered list - e.g. *F1, M1, F2, M2, M3, F3, ..., Fm, ..., Mn*. The constraints accumulate in a series of steps:

<sup>52</sup>Declarative phonology (Scobbie, Coleman and Bird 1997) does not accommodate (b) or (d), although extended versions have accommodated (d) *default* constraints.

(3)

- Stage 1: if an underlying representation does not satisfy **M1**, then the grammar derives from it the representation that best satisfies the hierarchy

$$F1 \gg \mathbf{M1} \gg F2 \gg F3 \gg \dots \gg Fm$$

- Stage 2: if that representation does not satisfy **M2**, then the grammar derives from it the representation that best satisfies the hierarchy

$$F1 \gg \mathbf{M1} \gg F2 \gg \mathbf{M2} \gg F3 \gg \dots \gg Fm$$

- *etc.*

Or, more generally:

- Stage  $k$ , for  $k=1,2,3,\dots,n$ : if the representation at stage  $k$  does not satisfy **M $k$** , then the grammar derives the representation that best satisfies the hierarchy containing **M1, M2, ..., M $k$**  (but not **M $k+1, \dots, M $n$$**   $k < n$ ) interleaved with all of the Faithfulness constraints  $F1, F2, \dots, Fm$ .

According to this approach, a phonological grammar has constraints placed in **cumulative order**. Each Markedness constraint is added in turn, so at successive stages an increasing number of constraints are operative. There is *serial* interaction because the constraints are added one at a time, there is *hierarchical* interaction because each constraint participates at all subsequent steps as a higher-ranked constraint, and there is *mutual* interaction because at each step previous constraints appear together with the newly added constraint. Where one constraint is ordered earlier than another, we shall say that that constraint is **pre-eminent** over the other, this pre-eminence having both serial and hierarchical implications. The name Constraint Cumulation Theory reflects the fact that the various interactional effects witnessed in phonology emerge as constraints accumulate. So, later constraints may render opaque the effect of earlier constraints; later constraints may act in concert with former constraints; and later constraints will

be of null effect when in conflict with earlier constraints. The effects of the constraints on the representation at each stage are determined in conjunction with the Faithfulness constraints, which are *all* present at every stage even though they are interspersed among the Markedness constraints in the ordering.

Faced with the choice, *constraints* rather than rules are adopted as the elements of phonological grammar. The difficulty with rules is that each Structural Description is fused with its own particular Structural Change, which does not allow at all for outcomes created by mutually supporting generalisations such as (1c). This requires several generalisations at once to influence a single step, as discussed by Prince and Smolensky (1993:124-125). Other difficulties with rules are pointed out in Scobbie (1991), Singh (1987), Sommerstein (1974), Shibitani (1973) and Kisseberth (1970a). In abandoning rules, CCT adopts the constraint-based view that processes are enacted to avert the violation of constraints. However, building derivations from the interaction of Markedness and Faithfulness constraints improves on earlier approaches that used constraints in derivations by providing not only for serial interaction, but also for the default behaviour and mutual interdependence between phonological generalisations highlighted in the Optimality Theory literature.

### 6.1.2 Descriptive Coverage

We illustrate CCT's descriptive coverage of the examples from non-standard Italian, Eastern Massachusetts English, Lardil and Yokuts that were given in (1). In the Italian pattern of vowel metaphony, vowel raising and vowel tensing both occur in forms like [priti] *priests*, from /pret/. We recognise the following two constraints as responsible for these processes:

(4) ALIGN = ALIGNLEFT([+high],Foot)

Every feature [+high] must be aligned to the left of a foot.<sup>53</sup>

\*+high/-ATR

Vowels cannot have both [+high] and [-ATR].

We illustrate the cumulation of these constraints in the order ALIGN before \*+high/-ATR. As laid out in (5), raising would be brought about at the step at which the Alignment constraint is included, and tensing would be brought about at the next step where \*+high/-ATR is included. This, then, works as a "feeding" order: raising is achieved at one step, tensing at the next step.

(5)

/prẽti/	ALIGN	
prẽti	*!	
↻ prẽti		
↓		
/priti/	ALIGN	*+high/-ATR
prẽti	*!	
priti		*!
↻ priti		
prẽti	*!	
↓		
/priti/		

<sup>53</sup>According to Calabrese (1995:445), metaphony is restricted to *final* feet. As it stands, the Alignment constraint does not incorporate this restriction, and so is correct only for words with one foot.

The same result obtains if ALIGN and  $*+high/-ATR$  accumulate in the opposite order. In that case,  $*+high/-ATR$  is included first, but to no effect, since the form /pɾeti/ already adheres to the constraint. At the subsequent step when the Alignment constraint is also included, the mutual effect of the two constraints will be to force the result /pɾiti/ at a stroke, as shown in (6).

(6)

/pɾeti/	$*+high/-ATR$	
	pɾeti	
	pɾiti	*!
↓		
/pɾeti/	$*+high/-ATR$	ALIGN
	pɾeti	*!
	pɾiti	*!
	pɾiti	
	pɾeti	*!
↓		
/pɾiti/		

A supporting generalisation, then, will take effect irrespective of the cumulative order. The two kinds of cumulation illustrated will each capture other important effects: the step-by-step nature of cumulation allows for the possibility of overapplication of some processes, while the presence of many accumulated constraints within a given step allows for the possibility of mutually interdependent processes. We illustrate these next.

The example of overapplication we have selected is the ban on tautosyllabic sequences of high vowel and liquid in Eastern Massachusetts English. In words like [fijəl] *feel*, epenthesis breaks up the offending sequence, but in words like [fijə] *fear*, epenthesis and *r*-deletion both occur, and the latter process removes one of the two segments that conditioned the epenthesis process. The relevant constraints are in (7).

- (7)  $*[+hi][+ap] ]_{\sigma} = *[+high][+consonantal,+approximant] ]_{\sigma}$

No tautosyllabic sequences of high vowel and liquid.

\*Coda/r

No *r* in the coda.

Cumulative Order:

$*[+high][+consonantal,+approximant] ]_{\sigma}$  before \*Coda/r before MAX-C

Placing  $*[+hi][+ap] ]_{\sigma}$  earlier in the order guarantees that it will take effect even though it is not surface apparent, in the classic serial-derivational fashion.

(8) /fi:r/		$*[+hi][+ap] ]_{\sigma}$	MAX-C
	fi:r	*!	
	☞ fi.jəɪ		
	fi:		*!
↓			

/fijəɪ/	*[+hi][+ap] ] <sub>σ</sub>	*Coda/r	MAX-C
fi:r	*!	*	
fi.jəɪ		*!	
☞ fi.jə			*

↓

/fijə/

Notice the importance of Faithfulness constraints participating at each step. At the second of the two steps, the optimal form violates MAX-C, and since this violation is not fatal MAX-C must be ranked lower than the two markedness constraints. Nevertheless, it is crucial that Faithfulness constraints are present at all steps, so that MAX-C is present at the first step to rule out /fi:/. Were /fi:/ to be selected, it would stand as the final outcome of the grammar - contrary to fact - since /fi:/ satisfies both constraints just using the single process of *r*-deletion, pre-empting epenthesis. This is precisely what we want to avoid if overapplication is to take effect.

Having shown that supporting-generalisation effects and overapplication effects can be readily accounted for in CCT, we may recall that these effects even occur simultaneously, as was demonstrated in 4.2. One such case is Turkish epenthesis and *k*-deletion (Orgun and Sprouse 1999): in derivations of words like *inek-m* → *inek-i-m* → *ine-i-m* ‘my cow’ with 1sg possessive suffix *-m*, epenthesis supports the occurrence of intervocalic *k*-deletion by supplying one of the vowels, while *k*-deletion removes one of the consonants in the cluster that prompted vowel epenthesis, causing it to overapply. Such a case is straightforward in CCT. For present purposes, we may employ an *ad hoc* constraint \*Vk]V that simply rules out *k* in the context where it is not found - intervocalically, in stem-final position. If we place this constraint within a cumulative

set, NOCOMPLEXCODA before \*Vk]V before MAX-V before MAX-C before DEP-V, then the result falls out correctly:

(9) /inekm/	NoCOMPLEX			
	CODA	MAX-V	MAX-C	DEP-V
inekm	*!			
☞ inekim				*
inem			*!	

↓

/inekim/	NoCOMPLEX				
	CODA	*Vk]V	MAX-V	MAX-C	DEP-V
inekim		*!			
inekm	*!				
☞ ineim				*	
inem			*!	*	

↓

/ineim/

Having demonstrated supporting-generalisation effects (1a) and overapplication effects (1b), Lardil provides our example of mutually interdependent processes (1c). If a noun stem is short, the nominative form will consist of the stem plus epenthetic segments to bring it up to disyllabic length. In the example [kaŋ.ka], augmented from stem /kaŋ/, an epenthetic *k* provides a syllable onset, with stem *ŋ* placed in the coda. The constraints in (10) are jointly responsible for this outcome.

## (10) CODACOND

A coda has no Place specification of its own, unless it is the unmarked Coronal place.

## ALIGNRIGHT(Stem, Syllable)

The right edge of a stem coincides with the end of a syllable.

Since these constraints act in a mutually interdependent fashion within a single step once they are both present, it is irrelevant which comes first in the cumulative order. We adopt the order CODACOND *before* ALIGNRIGHT(Stem, Syllable).<sup>54</sup> This yields the derivation in (11).

(11)	/kaŋ/	CODACOND		
		kaŋ	*!	
		kaŋ.a	*!	
		☞ ka.ŋa		
	↓			
	/ka.ŋa/	CODACOND	ALIGNRIGHT	DEP-C
		kaŋ.a	*!	
		ka.ŋa	*!	
		☞ kaŋ.ka		*
	↓			
	/kaŋ.ka/			

<sup>54</sup>As it happens, there is other evidence from Lardil in support of this order. In [ya.ka], from /yak/, the restriction on codas is respected and the final underlying consonant is syllabified as an onset, at the expense of true stem/syllable alignment (see Prince and Smolensky 1993 for full discussion). Stem/syllable alignment must therefore come later in the order, its effects being blocked by earlier constraints in such cases.

The syllabification of  $\eta$  in the onset at the first step counter to fact is easily revised at the second step, because there are no Faithfulness constraints requiring the retention of syllable structure (this is due to the fact that syllabification is not contrastive in language - see McCarthy 2003). Now at the second step, one or other of the two constraints can be satisfied depending on the syllabification of the  $\eta$  as  $ka\eta.a$  or  $ka.\eta a$ . However, both constraints can be satisfied at once at this step if an output with several fresh characteristics is selected:  $\eta$  syllabified in the coda, and an inserted homorganic stop syllabified in the following onset. Then the edge of the stem  $/ka\eta/$  does coincide with the syllable boundary, yet the Coda Condition is also respected since the Dorsal place specification of the  $\eta$  is not exclusive to the coda but is shared with the following onset.

Having seen how CCT predicts both overapplying processes and mutually interdependent processes, we finally turn to default processes. Syncope displays default behaviour cross-linguistically, since it fails to occur where it would leave behind consonant clusters that cannot be incorporated into other syllables. We assume that syncope is the loss of vowels falling outside of feet, following the analysis of Southeastern Tepehuan in Kager (1997). In (12) we give the relevant constraints for syncope in Yawelmani Yokuts.

(12) NOCOMPLEX

Syllable onsets and syllable codas must not contain two or more segments.

PARSE- $\sigma$

Syllables must belong to feet.

Cumulative Order:

NOCOMPLEX, MAX-C before DEP-V before PARSE- $\sigma$  before MAX-V

Since syncope defers to overriding syllable structure constraints, they must come earlier in the cumulative order than the syllable-to-foot parsing constraint which minimises vowels outside feet. This leads to the derivation of /kili:y a ni/ as in (13). There is an initial foot /ki.li:|/ (we shall not be concerned with the assignment of feet - see Archangeli 1991) and vowels outside it violate PARSE-σ. As a result, one is removed. We shall not be concerned here with the choice of vowel to be syncope, but with the issue of how the constraints suppress excessive vowel removal and compensatory epenthesis, which deviate from the default behaviour that is observed.

(13) /ki.li:|yani/

	NOCOMPLEX	MAX-C	DEP-V	MAX-V
☞ ki.li: .ya.ni				

↓

/ki.li: .ya.ni/	NOCOMPLEX	MAX-C	DEP-V	PARSE-σ	MAX-V
ki.li: .ya.ni				**!	
☞ ki.li:y .ni				*	*
ki.li:yn	*!				*
ki.li: .yin			*!	*	**

↓

/ki.li:y|.ni/

↓ (other changes)

/ki.ley|.ni/

In (13), there are potentially two unfooted syllables, and one is removed. Outputs with excessive vowel elision, deriving a *yn* coda or adopting a compensatory epenthetic *i* (/ki.li:yn|/, /ki.li:|.yin/), are rejected.

Neither would it be possible to delete a vowel at *one* step and insert *i* at a *subsequent* step, *yan*→*yn*→*yin*, because the NOCOMPLEX constraint that causes epenthesis is also present to prevent the *yn* cluster in the first place. Even if NOCOMPLEX were put *after* PARSE- $\sigma$  in the cumulative order, so that vowel deletion *yan*→*yn* is enforced at the first step by PARSE- $\sigma$  in the absence of NOCOMPLEX, it would still not be possible to epenthesise once NOCOMPLEX were added, since the more dominant PARSE- $\sigma$  would block any epenthesis outside the foot. Neither cumulative order produces re-insertion. Thus, CCT correctly rules out collapse of a vowel inventory down to the default vowel by deletion-and-epenthesis, which we argued in chapter 3 does not occur in language.

### 6.1.3 Selective Admission of Duke of York Derivations

The absence of these deletion-and-(re)insertion derivations, which would be revealed by inventory collapse  $V \rightarrow \emptyset \rightarrow i$ , demonstrated that the Duke-of-York derivations that are possible in rule-based phonology are not attested in language. We also cited McCarthy (2003) who claims that there is no evidence that intervening rules make crucial use of the intermediate stage between one structural change and its subsequent reversal. An example would be if syllables with (say) open vowels were lengthened to form heavy *Ca:* syllables, influencing rules of stress placement, then were made light (*Ca*) again in their surface form.

In CCT, these derivations are impossible. Cumulative order means that where two constraints make conflicting requirements on some context, the earlier one triggers its own process, and then blocks the outcome of the later one as appropriate. The later constraint is

unable to alter any effect of the earlier one owing to the continuing dominance of the earlier one. So, as just seen, epenthesis is triggered by syllable structure restrictions, and the pre-eminence of these restrictions blocks the opposite process of syncope, despite pressure from the syllable-to-foot-parsing constraint to remove vowels; for another example, labialised velars [k<sup>w</sup>] in Nootka are not permitted word-finally and are delabialised, but the constraint also blocks the opposite process of labialisation in the word-final position, even if the velar follows a rounded vowel, which is the right conditioning environment for labialisation: [...ok] \*...ok<sup>w</sup> (Pullum 1976, Sapir and Swadesh 1978); and so on. In all such cases, neither constraint *reverses* the effects of the other. Furthermore, since no process is applied and then reversed, there can never be any processes crucially triggered at some intervening stage - an apparently correct prediction.

Nevertheless, the two kinds of Duke of York derivation shown in (14) are attested, as pointed out in 3.4.5 and 5.3.3. These particular subtypes *can* be handled by CCT.

(14)

a. Reprosodification, e.g. Resyllabification: Compensatory Lengthening in Kinyarwanda (Walli-Sagey 1986)

/kuŋgana/ → [ku:˩ga.na] (long vowel takes timing slot of nasal)  
 \*[kuŋ.ga.na] (inadmissible CVC syllable)  
 \*[ku.˩ga.na] (no extra timing slot in 1st syllable)

b. Reversal in Absence of Conflict: Palatalisation before front vowels and Depalatalisation before coronals in Slovak (Rubach 1993)

/let En a:/ → [letna:] (alveolar before another coronal)  
 \*[letʰena:] (vowel realised; cons palatalised)  
 \*[letʰna:] (prepalatal consonant before coronal)

First, resyllabification. In Kinyarwanda, the timing sequence is set up by one syllabification, and preserved when syllabification changes. In the derivation in (16), the nasal contributes a timing unit to the first syllable at the first step. When it is ultimately realised as prenasalisation of the following stop, its timing slot is retained and allotted to the vowel, so that vowel length indirectly marks the presence of a nasal in the lexicon.

(15) PARSE-Segment

Segments must belong to syllables

NOCODA

Syllables do not contain codas.

MAX- $\mu$

Moras must be preserved.

Cumulative Order:

PARSE-Segment before NOCODA before MAX- $\mu$

These provide the following derivation:

(16)	/kuŋgana/	PARSE	MAX- $\mu$
	kuŋ.ga.na		
	↓		

/kuŋ.ga.na/	PARSE	NOCODA	MAX-μ
kuŋ.ga.na		*!	
ku. <sup>ŋ</sup> ga.na			*!
☞ ku. <sup>ŋ</sup> ga.na			

↓

/ku.<sup>ŋ</sup>ga.na/

In fact, change to syllable structure commonly accompanies change to the segmental string at successive steps, as has already been witnessed in the examples from Eastern Massachusetts English, Lardil and Yawelmani Yokuts. Assignment of new syllable structure at each stage is possible in CCT because there are no Faithfulness constraints covering prosodic structures, whereas there *are* Faithfulness constraints requiring the maintenance of features, segments and timing units conditioned *by* earlier syllable structures. Confinement of Faithfulness constraints to feature, segment and timing structure correctly accounts for the fact that only this material is contrastive in phonology (McCarthy 2003), and also successfully predicts the existence of resyllabification effects once the proposal to accumulate constraints over successive steps is adopted.

The facts in Slovak represent a different situation, where two conditions - for and against palatalisation - are relevant to mutually exclusive contexts. There are prepalatal consonants in Slovak, but they do not occur before coronal consonants, where they will be depalatalised, while dento-alveolars do not occur before front vowels, where they will be palatalised.<sup>55</sup> There can be

<sup>55</sup>Palatalisation does not apply morpheme-internally, e.g. [teraz] 'now'. This suggests the existence of a constraint that preserves the status quo when the underlying root is not prepalatal. On the other hand, underlying /l/ (but not /t',d',n'/) is resistant to Depalatalisation (Rubach 1993:268), so a further constraint preserves underlying lateral prepalatals. We shall not pursue these details of Slovak here, but we will consider further the case for constraints that preserve underlying specifications in 6.2.

no blocking of palatalisation by depalatalisation, or vice versa, simply because they never conflict. Instead, they interact indirectly as follows. In Slovak, palatalisation overapplies with respect to deletion of the yer vowel /E/ (yer vowels are lost except when preceding a syllable containing another yer vowel) as seen in the alternation [strela] 'shot'(N), [strel'ba] /strel+Eb+a/ 'shooting' (Rubach 1993:114); Depalatalisation "undoes the effect of Coronal Palatalization whenever Coronal Palatalization has applied before a yer-initial suffix containing a coronal consonant and the yer has not been vocalized" (Rubach 1993:267).

For the three conditions involved, we adopt the cumulative order *No Palatal* (\_\_\_Coronal) before *Palatal* (\_\_\_Front V) before *No Vocalisation* (i.e., "yer deletion"). This order takes into account the fact that palatalisation overapplies with respect to yer deletion. In (17), we see the steps of the derivation as the requirements of Palatal and No Vocalisation are added.

(17) /let En a:/

	No Palatal (___Cor)	Palatal (___E)
letEna:		*!
☞ let'Ena:		

↓

/let'Ena:/	No Palatal (___Cor)	Palatal (___E)	No Vocalisation
let'Ena:			*!
letEna:		*!	*
☞ letna:			
let'na:	*!		

↓

/letna:/

The coronal /t/ becomes prepalatal temporarily in the derivation, palatalising and depalatalising as its context changes. Since No Palatal does not conflict with Palatal, it does not prevent temporary palatalisation, even if it is pre-eminent.

This completes a survey of CCT's descriptive coverage of the different kinds of interaction between phonological generalisations. CCT, which was designed for the purpose of combining serial, hierarchical and mutual interactions of constraints, has the additional, unintended consequence that it admits the attested Duke-of-York derivations of resyllabification and reversal in absence of conflict, but does not admit unattested Duke-of-York derivations.

## 6.2 Predicting Underapplication and Overapplication

We have already seen how overapplication works in Constraint Cumulation Theory. Now, we observe that, although CCT is designed to incorporate serial interaction, the translation from rule-based derivations into this system is not complete. The interaction between Markedness and Faithfulness constraints in a cumulative system may be used to describe various underapplication phenomena, but it is sufficiently different from rule interaction to derive interesting constraints on overapplication and underapplication.

### 6.2.1 The Failure to Reproduce "Counterfeeding"

Constraint Cumulation Theory cannot directly reproduce the counterfeeding interaction that produces *underapplication* effects among rules, and instead will depend on pre-eminent Faithfulness constraints to cause underapplication. Whereas an ordered rule will fail to apply to the outputs of later rules, a constraint in a cumulative ordered set will instead be present as a potential filter at all subsequent stages. To see this, consider an example of a putative counterfeeding analysis from Malay. Low vowels in unstressed, light syllables reduce to schwa.

(18) Malay final vowel reduction (Zaharani 1998:144)

[dúgə][dugáʔan]	'to test, testing'
[súkə][sukáʔan]	'to like, favourite'
[mũlə][mũláʔi]	'to begin, to cause to begin'
[tʃíntə][tʃíntáʔi]	'to love, to cause to love'

Standard usage in Malay omits word-final *r*, although the current prescription in Malaysia based on literary Malay requires the *r* to be pronounced (Zaharani 1998:87). This creates examples of low vowels in unstressed, open syllables in the following words.

(19) (cited by Zaharani 1998:145)

<i>bakar</i>	[baka]	'burn'
<i>tukar</i>	[tuka]	'change'
<i>kisar</i>	[kisa]	'revolve'
<i>kindar</i>	[kinda]	'avoid'

The low vowels in the words in (19) are NOT reduced to schwa. This might suggest a counterfeeding rule-based analysis in which the *r*-deletion rule is ordered after the low-vowel-reduction rule so that the output of *r*-deletion does not undergo vowel reduction. Such an analysis cannot be reproduced in terms of cumulative constraints. Recasting the structural descriptions of the rules as constraints, we have a constraint prohibiting final light syllables with [a] ("NOLIGHT[a]" in Zaharani 1998) and another prohibiting syllable-final [r] ("ALIGN-RHOTIC" in Zaharani 1998). We do not obtain the same results if we reproduce the rule order "Vowel Reduction before *r*-Deletion" with NOLIGHT[a] before ALIGN-RHOTIC in a cumulative system. For the stems in (18), NOLIGHT[a] will correctly force vowel reduction, but vowel reduction will be triggered incorrectly on the stems in (19). The NOLIGHT[a] constraint is added to the active hierarchy first but to no effect; once the ALIGN-RHOTIC constraint is added, NOLIGHT[a] and

ALIGN-RHOTIC are both active, rejecting both *r*-final forms like [kisar] and *a*-final forms like [kisa]. The system incorrectly selects schwa-final forms like [kisə] to be the grammatical forms, since these satisfy both constraints.

In the Malay case, the counterfeeding analysis has in fact been discredited on grounds that the data in (19) is phonetically inaccurate. Whenever *rs* are deleted word-finally, the adjacent vowels are in fact compensatingly long, as in the data in (20). The extent to which vowel reduction occurs in Malay is accounted for merely if it is confined to short vowels. Indeed, the confinement of alternations to short elements and the corresponding stability of long elements is already recognised in phonology as the general principle of *geminate inalterability* (Steriade and Schein 1986).

(20) Malay final compensatory lengthening (Zaharani 1998:87,88)

[koto:]	[kotorran]	'dirty, dirt'
[uke:]	[ukerran]	'to carve, carving'
[uko:]	[ukorran]	'to measure, measurement'
[pasa:]	[pasarran]	'to market, market'

The failure to reproduce the counterfeeding interaction for the flawed Malay example in CCT reveals a general characteristic of the structure of cumulative constraint systems as divergent from ordered rule systems. Whereas a rule will not apply if it is ordered earlier, a cumulative constraint that is ordered earlier persists in its effects at later stages - it is even dominant over later constraints. This we take to be a potentially desirable result, for suspicion has consistently fallen on the counterfeeding analysis in phonology. It has been seen as a last resort, since it accounts for underapplication by a stipulation that is both language-specific and formally abstract (Booij 1997:277). Authors have sought to explain the failure of processes in other, more general ways, such as structural principles (like geminate inalterability in Malay) or

affiliation of the process to a stratum of rules applying only in the context of certain affixes. A strong proscription on counterfeeding *commits* the theorist to finding principled explanations of why processes fail. We claim that the failure of processes is always due to some pre-eminent constraint, whether it be a Markedness constraint or a Faithfulness constraint:

(21) **Why Processes Fail:** due to pre-eminent constraints

- a. Blocking using a Markedness constraint (*the process is excluded wherever it would create a proscribed phonological structure*)
- b. Prespecification using a Faithfulness constraint (*the process goes against an overriding requirement of faithfulness to a specification at the previous stage, so the process is only possible where no specification is provided*)

Blocking of syncope was witnessed in 6.1, and the Malay example is also a case of blocking.

Failure of processes due to prespecification is an approach promoted by Inkelas, Orgun and Zoll (1997). We shall extend it here in the context of the Constraint Cumulation system, applying it in the next section to underapplication effects in Modern Hebrew.

### 6.2.2 Prespecification: Modern Hebrew

Idsardi (1997) claims that in Modern Hebrew, postvocalic spirantisation overapplies with respect to syncope, and underapplies with respect to various processes of degemination, merger and deletion - purportedly supporting an ordered-rule analysis in which counterfeeding effects occur. Constraint Cumulation Theory can satisfactorily account for the overapplication of spirantisation in relation to syncope by placing a constraint against postvocalic stops into a cumulatively-ordered constraint set, and it can simultaneously account for the default behaviour of syncope by the pre-eminence of constraints on syllable structure, but the apparent

underapplication of spirantisation in the data cited by Idsardi (1997) is best understood in terms of faithfulness to specifications at previous stages of the grammar, extending the prespecification approach of Inkelas, Orgun and Zoll (1997).

The process of postvocalic spirantisation in Modern Hebrew (MH) is retained from Tiberian Hebrew (TH), the language of the Bible as annotated by the Masoretes (Idsardi 1997, Bolozky 1978).

(22) Modern Hebrew spirantisation (Idsardi 1997)

i.	pa <u>k</u> ax	'opened eyes'	ji <u>f</u> kax	'will open eyes'
ii.	li <u>s</u> por	'to count'	bi <u>s</u> for	'on counting'
	li <u>s</u> pox	'to pour'	bi <u>f</u> ox	'on pouring'
	li <u>m</u> kor	'to sell'	bi <u>m</u> xor	'on selling'

In (22i), we see a [p~f] alternation in the first stem consonant depending on whether it is preceded by a vowel. In (22ii), the second consonant of the stem alternates, despite the absence of preceding vowels in the surface forms. In the forms on the right, spirantisation is triggered by a preceding vowel which is syncope. In the forms on the left, syncope operates in the domain [li + stem] as part of the morpho- or lexical phonology, so that spirantisation, a word-domain process, operates on CVCCVC forms and so fails to spirantise the third consonant. In Tiberian Hebrew, stop-spirant variation was fully predictable - so the distribution of [+continuant] and [-continuant] is entirely specified by the grammar, and may be left unspecified in the lexicon (Idsardi 1998, 1997:372). Modern Hebrew has the spirantisation pattern, with a couple of special characteristics: only labials and voiceless velars [p~f b~v k~x] alternate in MH, and non-alternating /p b k f v x/ stops and fricatives occur as well as alternating ones. (23) lists various examples of non-alternating /p b k f v x/.

(23) Modern Hebrew /p b k f v x/ (quoted in Idsardi 1997)

a. *Historical merger /k/ < TH /q/*

kara	jikra	'read, will read'
kana	jikne	'bought, will buy'
pakax	jifkax	'opened eyes, will open eyes'
dakar		'stabbed'
zarak		'threw'

b. *Stops from historical geminates*

diber		'spoke'	< TH dibber
siper		'told'	< TH sipper
makar		'acquaintance'	< TH makkar
tabax		'cook'	< TH tabbax
tapil		'parasite'	< TH tappil

c. *Borrowings*

bilef	jebalef	'bluffed, will bluff'
pitpet	lepatpet	'talked a lot, to talk a lot'
mikroskop		'microscope'
zlob		'big, ungainly person'
fibrek		'fabricate'
falafal		'falafal'
fintez		'fantasised'
festival		'festival'

The /k/ in *pakax* (23a) is an important case in point, since it is a non-alternating obstruent co-occurring with an alternating one (p~f) in the same root. As Idsardi (1997:382) points out, this precludes an analysis in which certain roots are marked off as exceptional, and demands a phonological account in which some obstruents are alternating and some are non-alternating. Thus, in MH, we have a three-way distinction between /p/ specified in the lexicon as [-cont] (for *lepatpet* (23c)), /f/ specified as [+cont] (as in *fibrek* (23c)), and /P/ unspecified for [cont] in the lexicon (as in *pakax/jifkax* (23a)). Similarly we have /b/, /v/ and /B/ ([b~v]), and /k/, /x/ and /K/ ([k~x]). So we adopt the following constraints for MH:<sup>56</sup>

<sup>56</sup>Implicational constraints *Spirantisation* and *Stop* have been adopted here ahead of negative formulations (in prose "No stops following vowels"; "No fricatives") since implicational constraints succeed in filtering out the underspecified forms *Pakax* and *jiPkax* which would otherwise survive as the best outputs, incorrectly.

## (24) IDENT([continuant])

Every value of [continuant] specified in the input is preserved  
in the output.

*Spirantisation* [-sonorant]→[+continuant] / V\_\_

Obstruents are fricatives following vowels.

*Stop* [-sonorant]→[-continuant]

Obstruents are stops.

DEP([continuant])

Every [continuant] feature in the output must have an input  
correspondent.

Cumulative Order:

IDENT([continuant]), then *Spirantisation*, then *Stop*, then DEP([continuant])

Prespecified [-cont] or [+cont] is kept as it is by the IDENT constraint, while obstruents unspecified for [cont] are allotted [+cont] following a vowel by *Spirantisation*, or else [-cont] by *Stop*. These take effect one-by-one as in (25).

## (25)

/jiPkax/	IDENT([cont])	<i>Spirantisation</i>	DEP([cont])
jiPkax		*!	
jiPfax	*!		
jipkax		*!	*
☞ jifkax			*

↓

/jifkax/	IDENT([cont])	<i>Spirantisation</i>	<i>Stop</i>	DEP([cont])
jiPkax		*!	**	
jipkax	*!	*	*	
☞ jifkax			**	

↓

/jifkax/

/Pakax/	IDENT([cont])	<i>Spirantisation</i>	DEP([cont])
☞ Pakax		*	
Pafax	*!		
pakax		*	*!
fakax		*	*!

↓

/Pakax/	IDENT([cont])	<i>Spirantisation</i>	<i>Stop</i>	DEP([cont])
Pakax		*	*!*	
☞ pakax		*		*
fakax		*	*!*	*

↓

/pakax/

When the *Spirantisation* constraint is added, [jifkax] can be selected over *jipkax*, and when the *Stop* constraint is added, [pakax] can be selected over *fakax*. Hence, any features not specified in the lexicon will take unmarked values, while IDENT([cont]) ensures that prespecified values, such as k in /Pakax/, will not change even if *Spirantisation* is violated as a result.

In addition to causing the retention of prespecified stops and fricatives, the pre-eminence of IDENT([cont]) also preserves spirantisation effects that are subsequently opaque. In forms like [bisfor] (21ii), *Spirantisation* first takes effect, but when the conditioning vowel is subsequently lost, the *Spirantisation* constraint has no force to retain the fricative in the absence of the vowel, and the more general *Stop* constraint favours *bispor* over *bisfor*. But *Stop* is prevented from taking effect, and *Spirantisation* overapplies.

(26) *Why [bisfor] is not \*[bispor]*

bisaPor	Underlying Representation
↓	
bisafor	Spirantisation stage: /f/ in postvocalic environment
↓	
bisfor	Syncope stage: /f/ retained ahead of unmarked /p/ due to pre-eminence of IDENT([cont]) over <i>Stop</i>

This analysis also helps to explain the historical development of Hebrew. Tiberian and Modern Hebrew share this particular opacity effect whereby spirantisation overapplies with respect to syncope, fricative holding sway over stop. Hence, the IDENT([cont]) constraint is pre-eminent over the *Spirantisation* constraint in the phonology of Tiberian Hebrew also. Now, in Tiberian Hebrew, this leads to opaque specifications in the derivation but does not, as it happens, retain any lexical specification for there were none; all obstruents in the language alternated between

stop and fricative. But because the continuant/noncontinuant distinction was made in the grammar by the pre-eminent IDENT([cont]) constraint, it would always be possible for a nonalternating stop or fricative to emerge in the language: if a specification for [continuant] were ever made in the lexicon, then it would be preserved specifically by the pre-eminent IDENT constraint. This prediction is borne out precisely by the borrowings and internal changes that have produced the expected nonalternating obstruents in Modern Hebrew.

The pre-eminence of IDENT([cont]) in a cumulative system secures stop realisations rather than fricatives in various other data cited by Idsardi (1997) and analysed in terms of counterfeeding. A fact about Spirantisation in Modern Hebrew is that it is restricted to labials and voiceless velars. That is, the spirantisation process does not produce \*[θ ð ʎ], which are also generally absent from the Modern Hebrew consonant inventory. The obstruent inventory is given in (27), with the fricatives /f v x/ placed underneath their stop counterparts:

(27) *Modern Hebrew Obstruents*

p b t d k g    s z ts ʃ

f v    x

Markedness constraints \*[coronal, +continuant, -strident] and \*[dorsal, +continuant, +slack] affect both the inventory and the spirantisation process - a principled result in both source (markedness) and effect (wide-reaching restriction).<sup>57</sup> These constraints attain a pre-eminence in the grammar of Modern Hebrew they did not have in Tiberian Hebrew. The constraint against /y/ groups Modern Hebrew with German, Russian and Polish with which Hebrew was in contact

<sup>57</sup> Idsardi (1997:377-9) attempts to derive the restriction on spirantisation from the inventory itself - in the rule-based framework by banning the rule from producing outputs not in the inventory list (the "Structure Preservation" condition), or in OT by creating highly specific and complex IDENT constraints such as one to hold identical the structure of /g/.

over the centuries, all of which have /f v x/ but not /y/ (Idsardi 1997:377). The non-occurrence of /y/ has an interesting effect in connection with Regressive Voicing Assimilation.

(28) Regressive Voicing Assimilation (Idsardi 1997:378)

- a. [exzir] \*[eyzir] 'returned tr.'  
     [jixboʃ] \*[jiyboʃ] 'he will conquer'
- b. /ja-gasos/ → [jiksos] \*[jixsos] 'he will agonise'  
     /ja-gaxon/ → [jikxon] \*[jixxon] 'he will lean'

In (28a), regressive voicing assimilation fails to voice the velar fricative in careful speech, respecting the constraint. In the examples in (28b), the /g/, which fails to spirantise according to the constraint, nevertheless devoices to [k] by regressive assimilation. However, although [k~x] alternations exist in Modern Hebrew, this [k] does not. In Idsardi (1997), the analysis depends on rule ordering, so that the spirantisation rule does not apply because it is ordered before the regressive voice assimilation rule in a counterfeeding relation. Once more, however, the prespecification analysis explains the facts. /g/ does not undergo spirantisation; it is non-alternating. Therefore, it will be prespecified in the lexicon:

According to Prince and Smolensky (1993) ... that underlying representation is chosen which leads to the violation of the fewest highly ranked constraints in the generation of surface form. Each morpheme has exactly one best underlying representation. As a result, there is no reason to worry about indeterminacy in underlying representation. ... Not surprisingly, FAITH constraints will always favor a fully specified form in the absence of higher-ranked constraints forcing underspecification. Thus for structures which exceptionally fail to show the expected alternations and instead maintain a constant surface form, Lexicon Optimisation will naturally cause them to be stored underlyingly in their surface form - that is, to be prespecified. (Inkelas, Orgun and Zoll 1997:410-411)<sup>58</sup>

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<sup>58</sup>Idsardi (1997:382) questions Lexicon Optimisation, based on reports that mistakes and uncertainties occur among the three-way contrasts such as /k K x/ in MH. Thus, learners may make a non-alternating form alternating, or make an alternating form non-alternating. This does not falsify Lexicon Optimisation, however. Lexicon Optimisation is a linguistic principle which uniquely determines lexical representations from the surface representations. It does not say what happens when a human learner has been unable to establish a lexical representation from exposure to the language thus far, or is temporarily unable to access it, or otherwise chooses to construct another representation at the time of utterance. Such human factors inevitably superimpose on the basic linguistic system.

Either \* $\gamma$  or IDENT([cont]) would be sufficient to prevent /g/ from spirantising, but with regressive voicing assimilation (RVA), /g/ is devoiced to /k/, and it is IDENT([cont]) which continues to preserve the prespecified value [-continuant], so the /k/ fails to spirantise.<sup>59</sup>

(29) /ja-gasos/ 'he will agonise'

↓

/jigasos/	* $\gamma$	IDENT([cont])	<i>Spirantisation</i>	
jiγasos	*!	*	✓	
☞ jigasos	✓	✓	*	

↓

/jigasos/

↓

/jigsos/	* $\gamma$	IDENT([cont])	<i>Spir</i>	<i>RVA</i>
☞ jiksos	✓	✓	*	✓
jixsos	✓	*!	✓	✓
jiγsos	*!	*	✓	*
jigsos	✓	✓	*	*!

↓

[jiksos]

<sup>59</sup>This provides a successful account of regressive voicing assimilation effects in careful speech. In fast speech, the \* $\gamma$  constraint is not respected, giving [eγzir] 'returned tr.' rather than [exzir], and [jiγbof] 'he will conquer' rather than [jixbof] (Idsardi 1997:378). This is attributable to the activity of regressive voicing assimilation in a stratum beyond that which defines the shape of words, dealing with utterance pronunciation. It is characteristic of processes of this kind that they are variably applied - hence the alternation between "careful speech" utterances and "fast speech" utterances. There is no uniform resolution one way or the other between (a) faithfulness to the citation form of a word ("carefulness"), and (b) reducing its phonological shape for convenience at speed.

Other counterfeeding effects may also be accounted for. A number of mergers have shaped the Modern Hebrew consonant inventory, /q/ > /k/, /t̪/ > /t/, /s̪/ > /ts/, /ħ/ > /x/, /w/ > /v/, /ʕ/ > /ʔ/, and geminates have been degeminated. Idsardi (1997) assumes that these are rules added to the end of the Tiberian Hebrew rules, so that spirantisation will not apply to the outputs of these rules because it is ordered earlier,<sup>60</sup> as in the following:

(30)	jiqra	dibber	
	-----	-----	Spirantisation
	[jikra]	[diber]	Merger / Degemination
	'will read'	'spoke'	

The counterfeeding analysis suffers from the fact that the geminates and antiquated segments never surface, and the merger and degemination rules required for the analysis are not based on any observable processes in Modern Hebrew. They are rules of absolute neutralisation, merely devices to remove unattested phonemes and geminates. This is unnecessary abstractness, for if they are lexicalised in the form that is heard, they will be preserved in the surface form by the pre-eminent constraint IDENT([cont]) and will not be spirantised erroneously. In further data

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<sup>60</sup> Idsardi (1997:381) states that the spirantisation rule is a "feature-filling-only" rule. This is necessary in order to account for stops in loanwords in Modern Hebrew, and in fact renders superfluous appealing to rule ordering to prevent spirantisation in other cases, since it operates in just the same way as the present analysis: spirantisation will not at any stage alter an obstruent already specified. Idsardi also applies the feature-filling condition to Tiberian Hebrew, in which case derivations such as rabb → rab → rav 'large (sg.)' (Idsardi 1997:368) are in need of revision. The reference to features with no specification that is necessary for defining feature-filling rules adds significantly to the formal complexity of rules (Inkelas, Orgun and Zoll 1997), and compared to the constraint-based analysis they are also an essentially stipulative move. The distribution of a feature may be predictable (i) in all instances in words (ii) in some instances and not others (ternary contrast) (iii) in some contexts and not others (neutralisation). The ternary contrast in MH requires feature-filling so as not to disturb the nonalternating obstruents, but a neutralisation pattern requires a feature-changing rule. But the situation in TH is case (i), predictability in all instances, and this is achievable with either type (though the default feature value must be by filling not changing). The historical facts of Hebrew merely force the conclusion that the feature-filling option would have to have been taken by stipulation. By contrast, a universal grammar employing violable IDENT(F) constraints provides precisely the desired distinction: a neutralisation pattern (iii) for feature F means IDENT(F) is violated in the language, but where there are patterns of

where spirantisation fails to apply, a productive alternation affects words such as those in (31): root-initial /n/ is deleted from the future forms on the right, and such /n/-less forms consistently fail to show spirantisation of the second root consonant, even though it does spirantise in the perfective forms on the left.

(31)	nava	‘he derived from’	jiba	‘he will derive from’
	nafal	‘he fell’	jipol	‘he will fall’
	nafax	‘he breathed his last’	jipax	‘he will breathe his last’
	nifkad	‘he has been missing’	jipaked	‘he will be missing’

Idsardi (1997) adopts a rule-based analysis with geminate formation followed by a free ride on the degemination rule /nP/ → /pp/ → /p/. The spirantisation rule does not apply because it is ordered before the degemination rule (though its feature-filling status also prevents it from applying). However, the degemination rule is a rule of absolute neutralisation not based on any observable process in Modern Hebrew. Again, an analysis in which IDENT([cont]) is pre-eminent extends to this data. Relevant here is that MAX([cont]) must stand pre-eminent over markedness constraints on [continuant] in the cumulative order in Hebrew, just as IDENT([cont]) does, for [continuant] features are retained in derivations, neither changing in value nor deleting. These two constraints act in concert here. Although /n/ is deleted, the [-continuant] feature from the underlying /n/ is preserved to the surface by MAX([cont]). It docks onto the second root consonant /P/ which, being an alternating obstruent, lacks a [continuant] feature of its own. Despite the fact that this consonant is postvocalic and therefore required to be a fricative by the

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either total predictability (i) or ternary contrast (ii) for F, it is not violated. The naturalness of the TH-MH transition is confirmed since both sets of speakers would rank IDENT(cont) highly.

*Spirantisation* constraint, the pre-eminence of MAX([cont]) and IDENT([cont]) over *Spirantisation* secures a stop realisation at the expense of a *Spirantisation* violation.

In another pattern exemplified in (32), some plurals have postvocalic stops, even though the singular counterparts have fricatives:

(32)	kaf	'spoon'	kapot	'spoons'
	tof	'drum'	tupim	'drums'
	dov	'bear'	dubim	'bears'
	rav	'large sg.'	rabim	'large pl.'

Historically, the stops concerned were geminates, so in Tiberian Hebrew there was an alternation between intervocalic geminate stop and word-final fricative, e.g. *rav* / *rabbim*. Idsardi (1997:385) provides a complex rule-ordering analysis of (32) by positing underlying geminates for the Modern Hebrew forms. We could recast this in terms of a plausible constraint NoGeminates which, when added late in the cumulative order by the innovators of the change, suppressed the underlying geminates. However, the innovators may instead have simply failed to acquire geminates in their lexicon at all, and certainly modern learners exposed to data like (32) have no particular basis on which to set up geminates.

The alternation in (32) does not follow the usual stop / postvocalic fricative alternating pattern of Hebrew phonology; rather, what is displayed in (32) is irregular morphology. Thus, for a small class of words, plurality is marked by [-continuant] on the stem-final obstruent in addition to the suffix *-im*. Now the stops in alternations such as (32) are being lost from the language in favour of fricatives (Idsardi 1997:386). On our account, the fact and direction of this change are explicable. It is regularisation, a familiar process of morphological change, whereby the more widely-used pattern of plural-marking by

*-im* suffixation exclusively is being extended, and the uncommon added marking with stem-final [-continuant] abandoned.

Finally, Idsardi (1997) presents guttural deletion in Modern Hebrew and its effect on spirantisation. The gutturals /ʔ,h/ occur syllable-initially, but not syllable-finally, where they are deleted. For one class of glottal stops, deletion causes spirantisation of the following obstruent; in another class of glottal stops, spirantisation is blocked. Spirantisation is also blocked for deleted /h/.

(33)			<i>Spirantisation?</i>	Origin	
	/ʔKl/ <sup>61</sup>	joxal	'will eat'	<i>Yes</i>	TH/ʔ/
	/ʔBd/	mabad	'deed'	<i>No</i>	TH/ʕ/
	/hPK/	tapuxot	'instability'	<i>No</i>	TH/h/

The blocking of spirantisation here cannot be explained in the same way as in the case of deleted /n/ in (31), where the preservation of [-continuant] from the omitted /n/ phoneme ensured a stop rather than a fricative. Here we have deleted /h/ blocking spirantisation, which certainly supplies no [-continuant]. Instead, we adopt the constraint considered by Idsardi (1997) which rules out /ʔ,h/ in syllable coda by banning their superordinate feature [Guttural], placed after *Stop* in the cumulative order (34a). Then in the derivation of 'instability' (34b), deleted /h/ blocks spirantisation (obstruents are underlined at the stages where they are affected; obstruents that are already specified at an earlier stage are double-underlined):

<sup>61</sup>Despite the explicit proposal in Idsardi (1997) that alternating obstruents are underlyingly unspecified for [continuant], particular underlying forms were not given with the capitalised segments used in the text to signify the lack of full specification. We correct this here.

(34)

a. *NoGutturalCoda*      \**[Guttural]* ]<sub>σ</sub>

Cumulative Order:

IDENT([cont]) before *Spirantisation* before *Stop* before *NoGutturalCoda*

b. /tahPuKot/

↓      *Spirantisation*/tahPuxut/      /x/ spirantised, /t/ not spirantised since it is prespecified↓      *Spirantisation, Stop*/tahpuxot/      /p/ stopped↓      *Spirantisation, Stop, NoGutturalCoda*/tapuxot/      /h/ deleted; /p/ does not spirantise since already specified

‘instability’

We also require a way to distinguish the /ʔ/ of /ʔBd/, which blocks spirantisation, from the /ʔ/ of /ʔKl/ which does not. Idsardi (1997) distinguishes them in the lexicon by employing the original Tiberian Hebrew phoneme /ʕ/ along with /ʔ/ in underlying forms, which again we object to as abstract and unlearnable from exposure to Modern Hebrew. We propose that the lexical distinction in Modern Hebrew is between a glottal stop /ʔ/ and an underspecified guttural /ʔ/, lacking [constricted/spread glottis] features. Where /ʔ/ surfaces (in syllable onset positions), it is filled out by the grammar with the features of a glottal stop, the unmarked guttural. In coda positions, /ʔ/ is deleted in the same way as /h/ was in (34), blocking spirantisation. /ʔ/ has the same distribution, but we delete it early from the coda to allow spirantisation.

An additional coda condition (35a) is required banning the glottal stop specifically, placed early in the cumulative order so as to filter /ʔ/ but not /ʔ/. The derivations for ‘will eat’ and ‘deed’ in (35b) illustrate how spirantisation occurs in one case and not the other.

(35)

a. *No ʔCoda* \*ʔ]<sub>σ</sub>

Cumulative Order:

*No ʔCoda* before *Spirantisation* before *Stop* before *NoGutturalCoda*

b.	/jiʔaKal/	/maʔaBad/	
	↓	↓	<i>No ʔCoda</i>
	/joKal/	/maʔBad/	/ʔ/ deleted
	↓	↓	<i>No ʔCoda, Spirantisation</i>
	/jo <u>x</u> al/	/maʔBad/	/x/ spirantised
	↓	↓	<i>No ʔCoda, Spirantisation, Stop</i>
	/jo <u>x</u> al/	/maʔ <u>b</u> ad/	/b/ stopped
	↓	↓	<i>No ʔCoda, Spir., Stop, NoGutturalCoda</i>
	/jo <u>x</u> al/	/ma <u>b</u> ad/	/ʔ/ deleted, /b/ does not spirantise
	'will eat'	'deed'	

The loss of glottals from the coda by *No ʔCoda* is present in Tiberian Hebrew as well as Modern Hebrew, but general loss of Gutturals from the coda is an innovation. The cumulative order is in fact a reproduction of rule order in Idsardi (1997), Coda Glottal Deletion, Spirantisation, Stop

Formation, Coda Guttural Deletion, and the innovative element in both analyses comes at the end (of the rules, or of the active constraints).

This examination of the Modern Hebrew data raised in Idsardi (1997) demonstrates that underapplication can be described in CCT when the relevant Faithfulness constraint is pre-eminent over the relevant Markedness constraint. The presence of various postvocalic stops that fail to spirantise is analysed as prespecification either in the lexicon (exceptionality) or at a prior stage of the derivation (opacity), both of which are handled by Faithfulness over Markedness. More generally, Hebrew helps to illustrate the range of observable patterns that are available under Faithfulness over Markedness (F over M). In general, obstruents in the lexicon may or may not carry a [continuant] feature. If in some language all actual words with obstruents happen to carry a [continuant] feature, a simple stop:fricative contrast will be observed. Or if in all actual words with obstruents, none carries a [continuant] feature (as is claimed for Tiberian Hebrew), a predictable distribution of stops and fricatives will be observed. If some obstruents have a feature and some don't (as in Modern Hebrew), a three-way way contrast will be observed between stops, fricatives, and obstruents that alternate between the two. Such an alternation process shows underapplication. The situation with F over M contrasts with that of the opposite cumulative order, M over F, where outputs may sometimes be unfaithful, neutralising the relevant lexical distinctions. Distinguishing F over M from M over F gives rise to (36).

(36) **Hypothesis**

If a process underapplies (F over M) then it cannot neutralise (M over F);

if a process neutralises a contrast (M over F) then it cannot underapply (F over M).

We shall return to this hypothesis after incorporating some further underapplication phenomena into the theory.

### 6.2.3 More Underapplication: SOURCE constraints

We now consider evidence that derivations need to make continual reference to the underlying source, as well as to the form at a particular stage in the derivation. This comes from three further underapplication phenomena: *chain shifts*, *processes on derived structures*, and *subtractive morphology*.

In hypothesis (36) above, we have contrasted processes of neutralisation - which are predicted not to underapply, with processes of specification - which are predicted to underapply. Chain shifts are an additional phenomenon that do not fall within either of these types. Chain shifts have the form  $/A/ \rightarrow [B]$ ,  $/B/ \rightarrow [C]$ , ... , where a series of underlying forms  $/A/$ ,  $/B/$ , etc. are realised on the surface by the next in the chain. For example, vowels might raise to the next height level  $/a/ \rightarrow \varepsilon$ ,  $/\varepsilon/ \rightarrow e$ ,  $/e/ \rightarrow i$ . Chain shifts contain underapplication, since the process  $B \rightarrow C$  does not apply to those instances of  $[B]$  that are raised from  $/A/$ . Now processes in chain shifts are not processes of specification - they alter underlying specifications. But they are not neutralising either -  $/A, B/ \rightarrow [C]$  is specifically avoided. Serial application of constraint hierarchies, as is used in Constraint Cumulation Theory, does not lend itself well to this. For if we apply constraint hierarchies cumulatively, at one step we will get  $/A/ \rightarrow /B/$ , but on the next step we may expect the next shift  $/B/ \rightarrow /C/$  to be instantiated, erroneously giving overall  $/A/ \rightarrow /C/$ . Instead, the process  $B \rightarrow C$  must be constrained to apply to underlying  $/B/$  but not underlying  $/A/$ . This is the same problem as that pointed out by McCarthy (2000, 2002:159-162) for theories of *harmonic serialism*, in which outputs are re-submitted to a constraint hierarchy iteratively until no further change is possible (until "convergence").

The solution is that in addition to MAX constraints, that require maximum retention of features from one stage to the next in a derivation, we also need a family of constraints maximising preservation of features from the source form. We may call this constraint family

MAXSOURCE. We further assume the general ranking schema  $\text{MAXSOURCE}_\tau \gg \text{MAX}_\tau$  for all constraint pairs referring to the same feature tier, or more generally to the same structural tier,  $\tau$ . That is, preserving source structure is *more* important than preserving specifications at intermediate stages.

In (37), a chain shift is illustrated from a Spanish dialect. Vowels raise one level in height in the presence of the *-u* masculine singular suffix.

(37) Spanish dialect (McCarthy 2002:161, Hualde 1989)

	Stem	Fem Sg	Masc Sg	
a.	/nen/	néna	nínu	‘child’
	/sek/	séka	síku	‘dry’
b.	/gat/	gáta	gétu	‘cat’
	/blank/	blánka	blénku	‘white’

In (37a), mid vowels raise to high, in (37b), low vowels raise to mid. The chain shift generalisation is that on some particular scale (here, vowel height), there may be one MAXSOURCE violation but there cannot be two for the same segment in the same derivation. This is expressed by the additional device of local conjunction, as shown by Kircher (1996). Thus MAXSOURCE([high]) may be violated (37a), MAXSOURCE([low]) may be violated (37b), but the conjoined constraint  $[\text{MAXSOURCE}([\text{low}]) \text{ \& \& } \text{MAXSOURCE}([\text{high}])]_{\text{seg}}$  which measures violations of the two conditions within a single segment, remains intact, since only one feature, never both, is removed from the vowel.

In (38), we demonstrate how the features of *-u* spread. We use the abbreviation MS for MAXSOURCE; and  $\text{ALIGNHEIGHT} = \text{ALIGNLEFT}( [+high], \text{Word} ), \text{ALIGNLEFT}( [-low], \text{Word} )$ .

(38)

	MS([high])-&- MS([low])	ALIGNHEIGHT	MS([high])	MS([low])
/nen+u/				
nenu		*!		
☞ ninu				*
/gat+u/				
gatu		**!		
☞ getu		*		*
gitu	*!		*	*

(39) shows what happens at any subsequent stage. The value of MAXSOURCE constraints is that, in the subsequent accumulation of constraints at further steps, *\*gitu* can never be derived from /getu/ from underlying /gatu/ because the conjoined constraint still disallows changes in both [low] and [high] to the original /a/.

(39)

	MS([high])-&- &-MS([low])	ALIGNHEIGHT	MS([high])	MS([low])
/getu/				
gatu		**!		
☞ getu		*		*
gitu	*!		*	*

↓

/getu/



Subtractive morphology is a phenomenon where the underlying source is again significant. In subtractive morphology, a grammatical meaning is marked not by an affix but by an alteration to the stem. In that case, a MAXSOURCE constraint is violated – minimally – due to another constraint requiring the marking of some morphological category by a special deviation from the underlying source. Consider the case of Lardil nominals (Hale 1973, Itô 1986, Wilkinson 1988, Prince and Smolensky 1993) exemplified in (41). In the nominative, there is no affix, and the nominative case is characterised instead by the removal of final vowels (41a,b,c).

(41) Lardil nominals

	Stem	Nominative	Nonfuture Accusative	Gloss
a.	/yiliyili/	yiliyil	yiliyili-n	oyster sp.
b.	/mayařa/	mayař	mayařa-n	rainbow
c.	/yalulu/	yalul	yalulu-n	flame
d.	/kentapal/	kentapal	kentapal-in	dugong
e.	/ŋaluk/	ŋalu	ŋaluk-in	story
f.	/muŋkumuŋku/	muŋkumu	muŋkumuŋku-n	wooden axe
g.	/pulumunitami/	pulumunita	pulumunitami-n	young fem dugong

Nominative marking does not extend to deletion of consonants (41d), although final consonants are vulnerable to deletion on phonological grounds (41e), if they do not satisfy the restrictions on syllable coda. In Lardil, codas admit only nasals homorganic to a following onset or apical sonorants. This phonological deletion of consonants, which may accompany the deletion of the final stem vowel, tends to expose new vowels to final position in nominative forms (41f,g). The freshly exposed vowels are not deleted, only the truly stem-final ones, an apparent underapplication of final vowel deletion.

In the analysis of Prince and Smolensky (1993), a brute force constraint is placed in the hierarchy of constraints to enforce the nominative marking on the final vowel. Here, we adopt the

generalised REALISEMORPHEME constraint (Kurisi 2001).<sup>62</sup> In direct contrast to MAXSOURCE constraints, this constraint requires a deviation (any deviation) from the underlying source, specifically in order that a morphological category be marked. In (42), this constraint is ordered prior to the relevant MAXSOURCE constraint in order to force a realisation of the nominative case at the expense of the retention of the final vowel.

(42) REALISEMORPHEME

Every morphological feature present has a reflex in the output.

Cumulative Order: REALISEMORPHEME *before* MAXSOURCE-V

/muŋkumuŋku/

	CODA COND	REALISE MORPHEME	MAX SOURCE-V	MAX-V
.muŋ.ku.muŋ.ku.		*!		
.muŋ.ku.muŋk.	*!		*	*
.muŋ.ku.muŋ.	*!		*	*
☞ .muŋ.ku.mu.			*	*
.muŋ.ku.			**!	**

↓

/muŋ.ku.mu./

At subsequent steps in the cumulation of constraints, no further vowels are deleted or inserted, as shown in (43). Deletion of a further vowel is held back both by MAX-V and MAXSOURCE-V. An

<sup>62</sup>This approach contrasts with an alternative in which the subtracted form is measured against other members of the paradigm (Alderete 2001).

inserted vowel that restores identity with the underlier under a natural correspondence relation,<sup>63</sup> so satisfying MAXSOURCE-V, would nevertheless violate both DEP-V and REALISEMORPHEME.<sup>64</sup>

(43)

/muŋkumuŋku/

↓

...

/.muŋ.ku.mu./

	DEP-V	REALISE MORPHEME	MAX SOURCE-V	MAX-V
☞ .muŋ.ku.mu.			*	
.muŋ.ku.			**!	*
.muŋ.ku.muŋ.ku.	*!	*!		

↓

/.muŋ.ku.mu./

In a theory of violable constraints that requires violation to be minimal, the conflict between REALISEMORPHEME and MAXSOURCE constraints over identity or non-identity with the underlying source is resolved by at most one alteration to the stem, not two or more. It has been

<sup>63</sup>Extending use of the Correspondence assignment function, given for input-output pairs in chapter 2, I assume that, at each stage, potential output structures are assigned correspondence relations with (i) the form from the previous stage (ii) the underlying form. As shown in chapter 3, it is a corollary of the minimal constraint violation metric that a *natural* correspondence mapping is the most harmonic, hence natural correspondences are the ones considered.

<sup>64</sup>The basis for the pre-eminence of DEP-V over REALISEMORPHEME lies in other Lardil nominals such as *wife* \*wiŋa, where the expected *a*-epenthesis seen elsewhere in /yak/→yaka is not used. In this way, the stem is held identical at the expense of nominative case marking on such forms (Prince and Smolensky 1993, chapter 7).

claimed (Kurisi 2001) that this restriction on morphological marking on the stem holds across languages generally.

In this subsection, we have described further underapplication phenomena using constraints that require preservation of the underlying source: chain shifts, processes on derived structure, and subtractive morphology. Note that MAXSOURCE constraints serve a different function to MAX and DEP constraints, despite their overlapping effect: MAXSOURCE maximises the preservation of source material, while MAX and DEP have an operational function to minimise the differences between one stage of the derivation and the next (whether constructive or destructive). There is no DEPSOURCE constraint family to complement MAXSOURCE, since it would serve neither function. Precisely the same functional distinction is recognised for phonology by Paradis (1988, 1996, 1997) in her Preservation Principle and Minimality Principle. This position has further consequences in CCT, which we now examine.

#### 6.2.4 A Hypothesis

Source constraints aim to preserve underlying specifications, so where some markedness constraint is pre-eminent over MAXSOURCE, it forces neutralisation of underlying specifications, but where MAXSOURCE is pre-eminent over a markedness constraint, the markedness constraint cannot force processes in contravention of underlying specifications, and underapplies in respect of them. This dichotomy between neutralisation and underapplication only repeats hypothesis (35) made in connection with Modern Hebrew. But there is a further consequence now.

Neutralisation processes – or rather, processes caused by markedness constraints dominating all relevant faithfulness constraints – cannot *over*apply any more than they underapply.

To see this, consider a hypothetical example. Suppose all word-final obstruents devoice in a language which disallows labials in syllable coda, saving final labials by epenthesis to place them in the onset. Then for an underlying form like /kob/ i.e. with a final voiced labial, consider

the two possible outputs /kobe/ and /kope/. We certainly expect epenthesis, but the question is whether devoicing will occur. Suppose the constraint on voiced final obstruent is pre-eminent over the coda condition. Then we have the first step /kob/→/kop/. When the coda condition is added, leading to epenthesis, /.ko.pe./ and /.ko.be./ will both satisfy the coda condition, and *both* will satisfy the proscription against final voiced obstruents. Markedness does not decide between them, so it is down to faithfulness. /.ko.pe./ violates MAXSOURCE for voicing, since the source is /kob/, but /.ko.be./ is faithful to the source. There is a general prediction here: once a pre-eminent markedness constraint no longer discriminates between the two alternants because the context has changed, the relevant MAXSOURCE constraint favours a reversion to the underlying value. MAX and DEP constraints favour retaining the overapplied value from the previous derivational stage, but if, as we have assumed, MAXSOURCE<sub>τ</sub> is pre-eminent over MAX<sub>τ</sub> and DEP<sub>τ</sub> for each structural tier τ, restoration of the underlying value prevails and overapplication is rendered impossible. To demonstrate the generality of the result, an algebraic formulation is given in the box at the end of this section.

The prediction has currency in the empirical record. Neutralisation processes consistently fail to overapply or underapply. In Lithuanian (Kenstowicz and Kisseberth 1973:6), regressive voicing assimilation applies in consonant clusters, e.g. [ap]-*arti* 'finish ploughing' vs. [ab]-*gyventi* 'inhabit', but not to homorganic consonant clusters, which are broken up by epenthesis, e.g. [ap]-*i-begti* 'to run around'. Thus the process refrains from overapplication. Indeed, voicing assimilation never applies to consonants separated by epenthesis in any known language where the two processes co-exist (Kenstowicz and Kisseberth 1977:173). Several more examples of neutralisations and deletions which fail to overapply are quoted by Kenstowicz and Kisseberth (1973): Tübatulabal stop devoicing; Klamath preconsonantal neutralisation in glottalisation, aspiration, and voicing; Takelma preconsonantal devoicing/deglottalisation; Lithuanian metathesis and degemination; Yawelmani Yokuts apocope and vowel shortening; Washo vowel

drop and stress reduction; West Greenlandic Eskimo metathesis and high vowel lowering. Similarly, in Southeastern Tepehuan (Kager 1997), three neutralisation processes - intervocalic mutation of /v/ to [p] in reduplicated stems, conversion of voiced obstruents to pre-glottalised nasals in syllable coda, and complete assimilation of coda /h/ to the following consonant - are transparent, failing to overapply or underapply where they might conceivably have done when the surrounding vowels are deleted.

In contrast, observe that familiar examples of overapplication in phonology are those which instead *insert* material, and which thus offend no MAXSOURCE constraints. One example is Hebrew spirantisation which inserts the [+continuant] feature. The conditioning environment is a preceding vowel, but the process survives deletion of some of the vowels, an overapplication (see 6.2.2 above). In other cases, epenthesis breaks up consonant clusters of which one consonant may be subsequently deleted: examples include Eastern Massachusetts English fi:r → fi:jə, also Hebrew deʃʔ → deʃe (McCarthy 1999a) and Turkish inek-m → ine-i-m (Orgun and Sprouse 1999). Broadly, then, we have the following distinction:

(44)	<u>Transparent Application</u>	<u>Likely To Overapply or Underapply</u>
	Neutralisation	Conditioned Variation
	Deletion	Insertion

This dichotomy recalls the debates over rule ordering in phonology in the 1970s. The maximum utilization principle (Kiparsky 1968) which favours overapplication, and the minimisation of opacity principle (Kiparsky 1976) which favours transparency, fell foul of different examples. Kenstowicz and Kisseberth (1973, 1977) noticed that there were interesting subregularities, but articulated difficulties that held everyone back from finding a solution in the rule-based approach of the day:

The generalization that seems to emerge from the examples discussed above is that rules of assimilation, neutralisation, etc., tend to be predictably ordered to apply to "surface" rather than "abstract" syllable structure. .... However, when one begins to examine this "generalization" a number of difficulties immediately spring to mind. To cite just one example, many languages have the following two rules in their grammars: a rule palatalizing a consonant before *i*, and a rule of apocope. Given the claim that bleeding orders are expected between an assimilation rule and a rule affecting syllable structure, we would predict that the apocope rule should precede, and, hence, bleed the palatalization rule. Yet a cursory inspection of languages possessing these two rules indicates that a non-bleeding order is typical. Perhaps one might suggest that a non-bleeding order is preferred because the *i* which drops by apocope leaves a "trace" on the preceding consonant. We have not as yet examined the matter sufficiently to be able to determine if this suggestion is at all viable. (Kenstowicz and Kisseberth 1973:10)

Taking up these concerns, it is clear that assimilation to segments which are subsequently deleted may or may not go against the pattern in (44) - assimilation can be a form of neutralisation or of conditioned variation. Palatalisation may involve conditioned variation between assimilated and default allophones [t~c] or [k~ç]. However, if palatalisation, for example, brings about a neutralisation of contrast before /i/ between alveolar and palatal /t:/c/ or velar and palatal /k:/c/, and that /i/ is lost to apocope, then we have something which goes against the pattern in (44). Nevertheless, these *stability effects* are readily accommodated, given that contemporary phonological theory provides us with autonomous, spreadable features and Faithfulness constraints that can require the retention of features even when the segment they come from is deleted. The stability of the lateral gesture in the morphophonemic alternation of Klamath  $n_l \rightarrow lh$  due to MAX([+lateral]) illustrates in (45). This was first quoted in 1.2.1. In CCT, at the point where the constraint OCP {sonorant} is added, MAX([+lateral]) ensures that /lh/, which retains the lateral feature, is selected over /nh/.

(45)

/n<sub>l̥</sub>/

	OCP {sonorant}	MAX ([+lateral])	MAX ([+nasal])	DEP (Assoc)	MAX (Assoc)
n <sub>l̥</sub>	*!				
l <sub>l̥</sub>	*!		*	*	
lh			*	*	*
nh		*!			*

↓

/lh/

In CCT (unlike standard Optimality Theory) this strategy is available within a system that also allows for overapplication of insertive processes in serial interaction with other processes, thereby predicting opacity in all the places where it is found, and solving Kenstowicz and Kisseberth's puzzle.

*Stability effects* are of a kind with both *prespecification* and *chain shifts*, since in each case a pre-eminent Faithfulness constraint prevents a fully transparent solution. We may sum up this result as in (46):

(46) **Transparency of Pre-Eminent Markedness**

Markedness constraints that are pre-eminent over Faithfulness constraints for the affected material will be fully transparent in their effect, triggering structural alternations *when and only when* failure to do so would result in surface violation.

**Non-Transparent Cases:**

- i. **Prespecification:** pre-eminent Faithfulness constraint forces retention of feature in direct conflict to Markedness.
- ii. **Chain Shifts:** pre-eminent Faithfulness constraint excludes multiple changes to single phoneme in conflict to Markedness.
- iii. **Stability Phenomena:** a pre-eminent Faithfulness constraint salvages a feature from a deleted segment, causing a mutation to the adjacent segment whose cause is of course absent.

Except for stability effects, neutralisations and deletions are predicted to be transparent, as in

(47):

(47) **Transparency of Neutralisation Hypothesis**

Contextual neutralisation and elision of phonemes occurs if and only if the context in which it occurs is present in the actual surface representation, except when neutralisation is caused by assimilation to a phoneme that is deleted.

(47) is a prediction of Constraint Cumulation Theory on the descriptively necessary assumption that MAXSOURCE constraints are present, and on the further assumption that they are pre-eminent over their MAX and DEP counterparts. Constraint Cumulation Theory is a theory of Markedness-Faithfulness interaction which accurately predicts which processes must be fully transparent and which may be opaque.

### Nullification of Overapplication by MAXSOURCE

Consider structures  $p_0, p_1, p_2, p_{12}$ , where  $p_0$  is (isomorphic to) the underlying source form, and there is a disparity between  $p_1$  and  $p_0$  violating MAXSOURCE1 and MAX1, a disparity between  $p_2$  and  $p_0$  violating MAXSOURCE2 and MAX2, and both disparities between  $p_{12}$  and  $p_0$ . Let there be a Markedness constraint  $M_a$  which triggers  $p_0 \rightarrow p_1$ . That is,  $p_0$  violates  $M_a$ , and  $M_a \gg$  MAXSOURCE1  $\gg$  MAX1. Let there be a Markedness constraint  $M_b$  which triggers  $p_0 \rightarrow p_2$  &  $p_1 \rightarrow p_{12}$ . That is  $p_0, p_1$  violate  $M_b$ , and  $M_b \gg$  MAXSOURCE2  $\gg$  MAX1.

Let  $M_a \gg M_b$ . With  $M_a$  and  $M_b$  so defined, and without MAXSOURCE, this would be sufficient to trigger an overapplication of  $M_a$ ,  $p_0 \rightarrow p_1 \rightarrow p_{12}$ .

At the first step:  $M_a$  triggers  $p_0 \rightarrow p_1$  as normal

On the second step with  $M_a$  &  $M_b$ ,  $M_b$  disfavors  $p_0$  and  $p_1$ ;

$p_2, p_{12}$  both satisfy  $M_b$  and violate MAXSOURCE2;

$p_{12}$  additionally violates MAXSOURCE1;

$p_{12}$  is less harmonic (unless there is some saving constraint dominating MAXSOURCE1.

Hence,  $p_2$  wins.

#### 6.2.5 Transparency of Neutralisation: Yokuts

A more complex pattern, that of vowel qualities in Yawelmani Yokuts, provides a further significant test of the Transparency of Neutralisation Hypothesis. We begin straightforwardly.

High vowels are given in favour of mid when long, as in (48).

- |      |    |           |                 |                  |                   |
|------|----|-----------|-----------------|------------------|-------------------|
| (48) | a. | meek'-i-t | 'was swallowed' | cf. mik'aaʔan    | 'is swallowing'   |
|      | b. | ʔooʔ'-u-t | 'was stolen'    | cf. ʔuʔ'aaʔaanit | 'is to be stolen' |

Next, the application of mid height overapplies. The syllable inventory of Yokuts lacks closed syllables with long vowels, but when roots such as those in (48) come in closed syllables, the mid vowels are retained under shortening, as shown in (49).

- (49) a. mek-k'a 'swallow!'  
 b. ʔoʔ'-k'a 'steal!'

Previous accounts (Kuroda 1967, Kisseberth 1970, Kenstowicz and Kisseberth 1979, Archangeli 1983, 1985, 1988, 1991, Steriade 1986, Mester 1986, Archangeli and Suzuki 1997, McCarthy 1999a) have always held that there is neutralisation in height on long vowels, so-called "High Vowel Lowering". In Constraint Cumulation Theory, however, assuming the presence of MAXSOURCE constraints, the height alternation cannot be a neutralisation for then by Transparency of Neutralisation it would be incapable of overapplying. We would have a derivation like (50).

(50)

/miikk'a/

	NO LONG HIGHV	MAXSOURCE ([high])	MAX ([high])
.miik.k'a.	*!	✓	✓
☞.meek.k'a.	✓	*	*

↓

/.*mee*k.k'a./

	NOLONG HIGHV	FOOT- BINARITY	MAXSOURCE ([high])	MAX ([high])
. <i>miik</i> .k'a.	*!	*	*	*
. <i>mee</i> k.k'a.	✓	*!	✓	✓
. <i>mek</i> .k'a.	✓	✓	*!!!!	✓
● <sup>*</sup> . <i>mik</i> .k'a.	✓	✓	✓	*

↓

\*./.*mik*.k'a./

The first step *.Ci:C.* → *.Ce:C.* is predictable provided that the proscription against long high vowels is pre-eminent over MAXSOURCE([high]). However, on the second step when the vowel is shortened, *.CiC.* eclipses *.CeC.* because it reproduces the underlying height: although MAX([high]) favours retention of the lowered value of the previous stage, MAXSOURCE([high]) prefers the output with a high vowel matching the underlying form. The markedness constraint NOLONGHIGHV that prompts lowering at the previous stage is no longer pressing for a mid vowel, being vacuously satisfied because the vowel is short.

We conclude that since *.CeC.* shows up in the Yokuts data, it must be that there is no such underlying [+high]: instead there is underspecification. Then specification of [-high] on long vowels can overapply along the lines of (51):

(51)

/mIkk'a/

	NOLONG HIGHV	MAXSOURCE ([high])	MAX ([high])
.miik.k'a.	*!	✓	✓
☞.meek.k'a.	✓	✓	✓

↓

/.meek.k'a./

	NOLONG HIGHV	FOOT- BINARITY	MAXSOURCE ([high])	MAX ([high])
.miik.k'a.	*!	*	✓	*
.meek.k'a.	✓	*!	✓	✓
☞.mek.k'a.	✓	✓	✓	✓
.mik.k'a.	✓	✓	✓	*!

↓

/.mek.k'a./

Re-analysing the pattern as conditioned variation of height, to be handled by the insertion of [-high] and [+high], is analogous to the conditioned variation in Hebrew of stops and fricatives, handled by the insertion of [+continuant] and [-continuant]. Like the Hebrew pattern, the Yokuts vowel height alternation exhibits opacity. However, there is a further complexity in the Yawelmani Yokuts vowel pattern.

Vowel height is a crucial factor in vowel harmony in Yawelmani. If vowels agree in height, then they become completely identical. Three particular suffixes serve for expository examples in (52), but the effect extends to all suffixes. If the root vowel (if there are two they

will be identical) and suffix vowels are both high, then suffix vowels will take on all the features of the stem vowel, as in (52a,c). If stem vowel and suffix vowels are both non-high, then suffix vowels will take on all the features of stem vowels, as in (52b).

(52) a. -hIn, aorist I = high, realised {[i] or [u]}

xil-hin	'tangled'
hud-hun	'recognised'
c'om-hun	'destroyed'
xat-hin	'ate'

b. -Al, dubitative A = non-high, realised {[a] or [o]}

xat-al	'might eat'
bok'-ol	'might find'
k'oʔ-ol	'might throw'
hud-al	'might recognise'

c. -sIt-, indirective

t'ul-sut-hun	'burns for'
bok'-sit-k'a	'find (it) for!'

Although vowel harmony is pervasive in the language, its dependence on vowel height means that it is interrupted by the alternations in vowel height mentioned earlier:

- (53) a. meek'-i-t 'was swallowed' cf. mik'aaʔan 'is swallowing'  
 b. ʔooʔ'-u-t 'was stolen' cf. ʔuʔ'aaʔaanit 'is to be stolen'  
 c. c'oom-al 'might destroy'  
 d. doos-i-t 'was reported'

In (53a), the mid quality of long vowels is shown in a stem vowel which otherwise appears high (i.e. when it is not long). Alternating mid vowels behave as if high as far as vowel harmony is concerned: in (53b) spreading roundness to a high affix vowel, but in (53c), an alternating mid vowel does not spread to a non-high affix vowel. Note the contrast in behaviour between /o/ in

(53b), which behaves as high with respect to harmony, with /o/ in (53d), which does not. /o/-vowels that are not height-alternating as in (53d) are exceptional and will be prespecified with [-high]. Vowel Harmony, then, displays underapplication and overapplication with respect to Lowering: non-high affix vowels will not harmonise with lowered root vowels, and high affix vowels retain their harmony with lowered root vowels. Our established response is to say that roundness is conditioned: conditioned feature values are not specified underlyingly but filled in by the grammar. Then overapplication is expected, because it cannot be nullified by MAXSOURCE if there are no underlying specifications.

The difficulty is that roundness is conditioned by height, but height itself is also conditioned, and therefore not present underlyingly. If there is no underlying [+high], then it is difficult to see what the second vowel in *ʔooʔ'-u-t* can harmonise with. The specifications left undetermined by the grammar are now in (54).

(54)	Base Vowels			Affix Vowels		
		[low]	[high]	[round]	[low]	[high]
I	[i~u]	-		-	V [i~u~e~o]	-
U	[u~o]	-		+	A [a~o]	-
	o	-	-	+		
	a	+	-	-		

Cases like *ʔooʔ'-u-t* have been taken in the literature to show that such vowels are underlyingly [+high] and change to [-high] once vowel harmony has been instantiated (*ʔuuʔ'-i-t* → *ʔuuʔ'-u-t* → *ʔooʔ'-u-t*). The alternative analysis is that [+high], rather than being prespecified underlyingly, is temporarily inserted in the derivation, as a default. The default nature of [+high] has cross-

linguistic support (Archangeli 1988). Its insertion will be required by the well-formedness constraint "every vowel must be associated to a [high] feature" (WF). WF recalls other well-formedness requirements in autosegmental phonology, e.g. "every tone-bearing unit must be associated to a tone" (Goldsmith 1976) which we assume generalises to any two tiers whose elements associate. [+high] is made the default by utilising the claim that phonological constraints refer to marked structure (Inkelas 1994, following a proposal given by Paul Kiparsky at the TREND conference in 1994). Then we have Faithfulness constraints DEP([high]) and the more specific DEP([-high]), MAX([high]) and the more specific MAX([-high]), which make reference to the marked [-high]. This predicts, correctly, that unmarked features are inserted more generally and deleted more generally than marked ones cross-linguistically.<sup>65</sup>

This leads to the following derivations (I,U,V are as defined in (54): I=[-low,-round], U=[-low,+round], V=[-low]):

(55) Constraints in Cumulative Order:

MAXSOURCE([high]) *before* WF *before* Harmony *before* NoLongHighV *before*  
 FootBinarity *before* MAX([high]) *before* MAX([-high]) *before*  
 DEP([high]) *before* DEP([-high])

<sup>65</sup>This proposal replaces that of context-free markedness constraints of the form \*[m feature], e.g. \*[-high]. These have persisted in the OT literature (Kager 1999, McCarthy 2002) despite the correct prediction of F([m feature]) constraints cited in the text. Here in Yokuts, a context-free markedness constraint \*[-high] would fail, since in order to insert default high vowels it would have to dominate the later-added NoLongHighV, and would therefore wrongly suppress the formation of long mid vowels.

- |    |                             |                            |   |
|----|-----------------------------|----------------------------|---|
| a. | ʔUU <u>ɥ</u> '-V-t          | c'UU <u>m</u> -hVn         |   |
|    | ↓                           | ↓                          | <i>WF</i>   |
| b. | ʔ <u>uu</u> ɥ'-I-t          | c' <u>uum</u> -hIn         | All vowels given [+high] by default                 |
|    | ↓                           | ↓                          | <i>WF; Harmony</i>                                  |
| c. | ʔuuɥ'- <u>u</u> -t          | c' <u>uum</u> -h <u>un</u> | Suffix vowels harmonise with root vowels            |
|    | ↓                           | ↓                          | <i>WF; Harmony; NoLongHighV</i>                     |
| d. | ʔ <u>oo</u> ɥ'- <u>u</u> -t | c' <u>oom</u> -h <u>un</u> | Root vowels lower; suffix vowels retain [+high]     |
|    | ↓                           | ↓                          | <i>WF; Harmony; NoLongHighV; FootBinarity</i>       |
| e. | ʔ <u>oo</u> ɥ'- <u>u</u> -t | c' <u>om</u> -h <u>un</u>  | <i>c'om</i> vowel shortened, but retains mid-height |

As the Well-Formedness constraint is added, the least costly way of satisfying it is to add [+high] features, avoiding violation of DEP([-high]) (55b). Because the vowels share the same height, Harmony attributes [+round] to them both too (55c).<sup>66</sup> Harmony now overapplies with respect to Lowering at (55d) because when the root vowels lower to satisfy NoLongHighV, [+high] is retained by the suffix vowels due to the influence of MAX([high]). Finally, Lowering overapplies again with respect to shortening, with MAX([high]) retaining the /o/ in /c'omhun/.<sup>67</sup>

In Constraint Cumulation Theory, the marked Faithfulness constraints influence every stage of the derivation, since Faithfulness constraints are present at every stage, so when a well-formedness constraint calls for a feature, it is the unmarked one that will be provided. An

<sup>66</sup>According to the representational system of Mester (1986), harmony follows from the constraint OCP([high]). In fact, the order of WF and OCP([high]) is not crucial: they might both be added at the same step and determine vowel features in parallel.

<sup>67</sup>This is an unnatural derivation in the sense defined in chapter 3. The [+high] is not in the underlying form or the surface form, and therefore invisible in the underlying-surface correspondence mapping. It is only detected indirectly by its influence on other vowels in vowel harmony. It has been claimed by Steriade (1986) and Mester (1986) that Harmony and Lowering belong to different strata of the grammar, one applying after the other. These 'strata' correspond to subportions of the derivation which are themselves natural ( $\emptyset \rightarrow [+high]$  and  $[+high] \rightarrow [-high]$ ), and each portion produces well-formed vowel-height association, whether [+high] or [-high].

analysis with a temporary insertion of the default [+high] during the portion of the derivation where vowel harmony is determined formally reflects the fact that long mid vowels behave as high for purposes of harmony. In fact, the presence of marked Faithfulness constraints predicts that only unmarked features can be inserted temporarily in a derivation and have opaque effects such as that seen in Yokuts: this is an *opaque emergence-of-the-unmarked* effect. In this way, the added effect of vowel height on vowel harmony, which involves overapplication and underapplication, still submits to an analysis in which the [high] feature is specified by the grammar, as the Transparency of Neutralisation Hypothesis (47) predicts.<sup>68</sup>

The analysis brings Yawelmani Yokuts into line with the underspecification / prespecification approach developed in Inkelas (1994) and Inkelas, Orgun and Zoll (1997), taken up here in Constraint Cumulation Theory to derive new predictions about opaque interactions. Following Inkelas (1994), the underspecification employed is based not on principles governing lexicon forms, but on the actual surface alternations. The underlying forms are ones that are consistent with the Markedness-Faithfulness interactions that describe the alternations, and are not based on direct constraints on the input or on the lexicon, in accordance with the Richness Of The Base principle, which is Optimality Theory's legacy in our understanding of the lexicon.<sup>69</sup> It is also a feature of our analysis that prespecification is possible, creating exceptions to the effect. This prediction too is borne out by instances of /o/ such as /doosit/ which, being specified as

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<sup>68</sup> Another problematic aspect of the vowel height pattern in Yawelmani Yokuts noted by Sprouse, Inkelas and Orgun (2001) produces another unnatural derivation, which appears to go against the tight Duke of York limitations in CCT given in 6.1.2, and it is difficult to see whether it may submit to a temporary-default treatment. *sognut* is derived from underlying /sugnit/, where lowering of the first vowel crucially depends on morphologically-conditioned vowel length at an intermediate stage before shortening to fit syllable structure, /u/ → u: → o: → o .

<sup>69</sup> Archangeli and Suzuki (1997) propose that the *input markedness* constraint,  $V \approx [+high]_I$  "Input vowels must be [+high]" is necessary to ensure that Yokuts [e:] is lexicalised /i/ even in cases where it never surfaces high, so that it will be predicted to behave as a high vowel for purposes of vowel harmony. In doing so they abandon the Richness of the Base principle, claiming instead that constraints on the input mirror the output markedness constraints. This must be combined with two further technical innovations, *disparate correspondence* constraints, and the *input-else* constraint condition, to complete their account of opacity in the Yokuts vowel system. This is an unwelcome proliferation of devices, and, as has been shown by Idsardi (1997) for Hebrew, the approach fails to provide an adequate account of the historical development of patterns it describes.

[-high], does *not* behave as high with respect to harmony. However, McCarthy (1999a) emphasises the lack of an /e/ in Yokuts to complement the /o/. He therefore proposes an alternative analysis in which vowels in Yokuts participate in a chain shift that steps down in height  $i: \rightarrow e(:) \rightarrow a(:)$ , and uses this to explain the lack of /e/, unlike /o/, in underlying forms: [e]/[e:] will be lexicalised as /i/, since /e/ is realised as [a(:)] by the chain shift. Nevertheless, the naturalness of the chain shift analysis is compromised by several caveats: *short* /i/ is specifically excluded; back vowels also lower, but only from high to mid and *not further*; and in the Wikchamni dialect of Yokuts, a *raising* process takes short mid vowels in the opposite direction. This complexity is avoided on our account by the use of the single constraint NoLongHighV, but with pre-eminent Faithfulness, creating conditioned variants [i]/[e:] [u]/[o:] which admit – as expected – both exceptions and opacity. We have not explained the lack of non-alternating /e/ (or /i/ or /u/) on our account, but it may well be right *not* to attribute the lack of /e/ to the grammar, since the explanation may lie in language learning and use, as follows. Phonetic [o], when followed by the frequent vowel [i] as in [doosit], *must* be /o/ and not the underspecified vowel /U/ underlyingly because if it was /U/, it would have caused rounding to the [i]. This reinforces the lexicalisation /o/. By contrast, [e] when followed by the same frequent vowel [i] looks as if it *could* be a lowered form of /I/, as it is in [meek'it]. The fact that the vowel harmony pattern reinforces /o/, but not /e/, suggests that /o/ will be more stable.

### 6.3 Conclusion

Constraint Cumulation Theory is a synthesis of serial and hierarchical interaction between phonological constraints. Its predictions match the empirical record at many points, deriving patterns of overapplication, mutual interdependence, default, reproductification, reversal in absence of conflict, prespecification, chain shifts, processes confined to derived structures, subtractive morphology, stability effects, and multiple overapplication.

These depend on an interaction between Markedness constraints, added cumulatively, and Faithfulness constraints which not only regulate each step of the derivation but also measure the retention of underlying specifications. Along with this, the twin strategy of underlying specification versus default specification (Zwicky 1986) is harnessed: contrastive features are specified underlyingly, while features whose values alternate are not, allowing default values to be inserted. This approach has been tested against the more complex patterns in Modern Hebrew and Yawelmani Yokuts, in addition to a range of other examples.

The cumulation of constraints at successive constraint evaluations contrasts with an approach in which iterative constraint evaluation uses the same constraint hierarchy repeatedly (“Harmonic Serialism”, Prince and Smolensky 1993), and CCT's wide descriptive coverage dwarfs the limited capacity of this system (see McCarthy 2000). Another alternative, Derivational Optimality Theory (Rubach 1997, 2000), uses slight variations in the constraint hierarchy over two or three iterations in order to account for complexities in Slavic languages, but lacks the general prediction of Transparency of Neutralisation that comes from the cumulative interaction of constraints constructed here. Other proposals embellish Optimality Theory with additional mechanisms: Sympathy Theory (McCarthy 1999a) derives opacity effects by nominating privileged *selector constraints* that pick out ‘sympathetic’ forms which influence the final outcome; Enriched Input theory (Sprouse, Inkelas and Orgun 2001) derives opacity by admitting *input constraints* that apply not to outputs but to a set of inputs generated from the underlying structure. There may be subtle predictive differences of complexity that can help distinguish between these theories and CCT, but both of them involve an added device which must be stipulated every time there is opacity, offering a less natural account of learning and historical evolution. By contrast, CCT derives opacity from the *same* mechanism as other effects, the cumulative order of constraints. Finally, Optimality Theory’s antecedent, Rule-based phonology, has always drawn a significant amount of support from opacity effects (Dresher

1981, Idsardi 2000). However, it has been ill-equipped to solve the problem of predicting and constraining opacity, even though subregularities were observed informally (Kenstowicz and Kisseberth 1973, 1977). The solution in CCT draws on the resources of contemporary phonology, obtaining the patterns that are observed through the effect of feature-Faithfulness constraints in the course of derivations.

7:

## CONCLUSION

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In the course of this work, we have set out and conducted a programme of formal theory comparison for derivational phonology and optimality phonology, finally setting up a new system that successfully responds to the empirical issues raised in the course of the study.

The enterprise of formal theory comparison examines how similar theories are structurally, an approach distinct from comparisons of data, substance and semantics. The two theories we were interested in employed generation systems and evaluation systems, and we sought to compare these while avoiding such formal red herrings as the blocking of rules, and the Generator function found in expositions of Optimality Theory. These foundational considerations were established in the first two chapters.

Derivational phonology and optimality phonology are comparable on three fronts: rule operations and Faithfulness constraint violations; serial rule interaction and evaluative constraint interaction; derivational sequences and harmony scales. In each case, the correlation breaks down and pertinent data emerge. The Duke of York gambit proved to be a recurring issue in all of them, and we comment on this further below.

A synthesis of the two systems was demonstrated in chapter six. It places an ordering on constraints which acts both as a serial order and a rank order. This maximises descriptive coverage of the interactions that are possible between phonological constraints in the world's languages. The theory matches all the empirical requirements that emerged during the formal comparison in earlier chapters, but also puts interesting limitations of its own on opacity effects, such that neutralisation is normally transparent.

## 7.1 The Duke of York Gambit

Of recurrent significance in this work has been the “Duke of York gambit”, so named by Pullum (1976). Formal comparison has clarified the nature of the Duke of York gambit, and a fresh evaluation of its merit has been given here. It has often appeared suspect to phonologists, and we have argued (3.4.2) that it is problematic because it fails to explain why alternant forms are similar when they are. We have also argued from empirical evidence that the Duke of York gambit is not used in natural language, except in some subcases. For, if the Duke of York gambit were possible, then we would predict languages where vowel deletion and vowel insertion caused the vowel inventory to collapse to one vowel in some contexts. But this never happens: instead, vowel deletion and vowel insertion apply in disjoint contexts, as seen in Yokuts, Chukchee and Lardil (3.4.4).

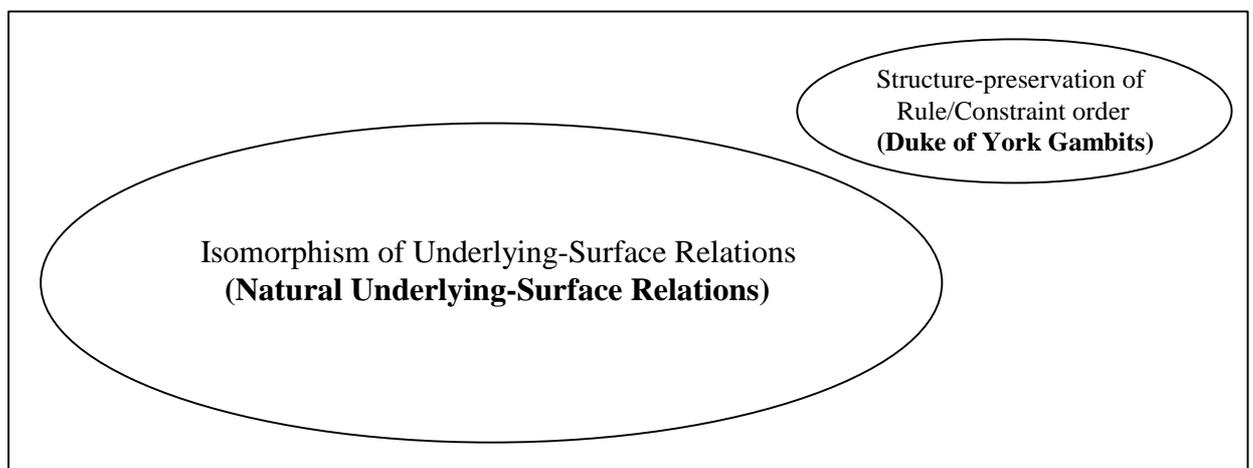
In fact, the Duke of York gambit is pivotal to the entire formal comparison. We showed that Duke of York derivations exceed definable 'naturalness' properties applicable to the formal structure of derivations:

- Duke of York gambits are prime examples of derivational subsequences that are **unorderedable** since they contain a repeated element (see chapter five),
- Some Duke of York gambits, those which destroy inserted material, constitute **non-cumulative** derivations which cannot be replicated by multiple changes at a single step and the serial composition of the mappings of the two contrary operations is not **representative** of the two component steps (see chapter three).
- All other Duke of York gambits are not **veritable**, because the resulting structure is identical in some respect to the original but this is left as an accident of the system, whereas leaving the structure unaffected would have satisfactorily explained the before-and-after resemblance (see chapter three).

In contrast, the input-output correspondences and harmony scales of constraint evaluation systems are well-behaved in these respects. So mappings like insertion-deletion do not arise in a one-step input-output theory, and mappings like deletion-insertion, are always filtered out as containing excessive Faithfulness constraint violations. A Duke of York derivation can never be isomorphic to an input-output mapping; equivalently, if we consider all the possible pairings of rewriting systems and evaluating systems that have isomorphic underlying-surface relations, Duke of York derivations are not among them. Duke of York derivations may derive the same *results* as some of these systems which lack them, but the gambit exceeds the naturalness properties that these other systems share.

It is considerably ironic, then, that whereas the Duke of York gambit is mismatched with constraint evaluation in terms of its mapping structure, it is actually the place where rule ordering and constraint ranking match up: whereas the rule whose outcome supersedes the other is ordered later, the analogous constraint whose effect supersedes the other is ranked higher. Hence, there is no common ground between the correlation of rule ordering and constraint ranking (the Duke of York gambit cases) and systems that have isomorphic underlying-surface relations. A Venn Diagram (1) puts this lack of common ground into graphical form.

(1) **Venn Diagram** over the space of pairs of generation systems and evaluation systems:



(1) represents the overall conclusion of our formal comparison of the derivational framework and the optimality framework: that while substantial **correlations** exist between the two systems in terms of the mapping between underlying and surface structures, and in terms of rule interaction and constraint interaction, the fact that these connections are mutually exclusive means that at no point do the two systems **mimic** each other in full. And the Duke of York gambit is precisely where this lack of mimicry is demonstrated, for just at the place where rule/constraint interaction converges, the underlying-surface relation diverges.

## 7.2 A New Synthesis

Constraint Cumulation Theory vindicates the formal comparison enterprise. Developed as a formal integration of serial order and rank order, its predictions match the empirical record at many points, deriving examples of overapplication, mutual interdependence, default, reprosodification, reversal in absence of conflict, prespecification, chain shifts, processes confined to derived structure, subtractive morphology, stability effects, and multiple overapplication. These patterns depend on an interaction between Markedness constraints, added cumulatively, and Faithfulness constraints which not only regulate each step of the derivation but also measure the retention of underlying specifications. This brings together the insights of derivational phonology and optimality phonology.

Providing more than a consolidation in descriptive coverage, desirable though that is, Constraint Cumulation Theory also excludes unattested Duke-of-York derivations while accommodating attested subtypes, and limits the ways in which neutralisation can become opaque:

(2) **Transparency of Neutralisation Hypothesis** (6.2.4)

Contextual neutralisation, and phoneme elision, occur if and only if the context in which they occur is present in the actual surface representation, *except* when neutralisation is caused by assimilation to a phoneme that is deleted.

This offers a fresh insight into the traditional distinctions between neutralisation and conditioned variation, and between elision and epenthesis. It also invites further investigation: if neutralisation and deletion are constrained from becoming opaque, do other processes *always* become opaque where possible? For example, given Eastern Massachusetts English *fear* [fi:.jə], is it plausible that a variety of English could exist where epenthesis did *not* overapply with respect to *r*-deletion, leaving *fear* homophonous with *fee* [fi:]? Or is epenthesis inevitable in this context? Another issue is that phonetic studies of some cases of neutralisation have suggested that neutralisation is not phonetically complete, perhaps suggesting that neutralisations should not be dealt with by the discrete, categorial features of phonology at all (Port and Crawford 1989, but see Fourakis and Iverson 1984 for a dissenting view). The view presented here must be evaluated against this alternative.

## REFERENCES

- Alderete, J. (2001), Dominance effects as trans-derivational anti-faithfulness. *Phonology* 18:201-53.
- Allen, W. (1957), Aspiration in the Hārautī nominal. In *Studies in Linguistic Analysis*, special volume of the Philological Society. Blackwell: Oxford.
- Anderson, S. (1985), *Phonology in the Twentieth Century: Theories of Rules and Theories of Representations*. University of Chicago Press: Chicago.
- Anderson, J. and C. Ewen (1987), *Principles of Dependency Phonology*. Cambridge University Press: Cambridge.
- Archangeli, D. (1983), The root CV template as a property of the affix: evidence from Yawelmani. *Natural Language and Linguistic Theory* 1:347-84.
- Archangeli, D. (1985), Yokuts harmony: evidence for coplanar representation in non-linear phonology. *Linguistic Inquiry* 16:335-72.
- Archangeli, D. (1988), Aspects of underspecification theory. *Phonology* 5:183-208.
- Archangeli, D. (1991), Syllabification and prosodic templates. *Natural Language and Linguistic Theory* 9:231-83.
- Archangeli, D. and D.T. Langendoen, eds. (1997), *Optimality Theory: An Overview*. Blackwell: Oxford.
- Archangeli, D. and D. Pulleyblank (1994), *Grounded Phonology*. MIT Press: Cambridge, Mass.
- Archangeli, D. and K. Suzuki (1997), The Yokuts challenge. In Roca, ed. (1997a), pp. 197-226.
- Batóg, T. (1967), *The Axiomatic Method in Phonology*. Routledge & Kegan Paul: London.
- Bird, S., ed. (1991), *Declarative Perspectives on Phonology*. Centre for Cognitive Science, University of Edinburgh.
- Bird, S. (1995), *Computational Phonology: A Constraint-Based Approach*. Cambridge University Press: Cambridge.
- Bird, S. and E. Klein (1990), Phonological events. *Journal of Linguistics* 26:33-56.
- Bird, S. and D.R. Ladd (1991), Presenting autosegmental phonology. *Journal of Linguistics* 27:193-210.
- Bird, S. and T.M. Ellison (1994), One level phonology: autosegmental representations and rules as finite automata. *Computational Linguistics* 20:55-90
- Blevins, J. (1997), Rules in optimality theory: two case studies. In Roca, ed. (1997a), pp.227-60.

- Bloomfield, L. (1926), A set of postulates for the science of language. *Language* 2:153-64. Also in M. Joos, ed. (1957), *Readings in Linguistics I: The Development of Descriptive Linguistics in America, 1925-56*, University of Chicago Press: Chicago, pp.26-31.
- Bolognesi, R. (1996), Language-particular constraints in an open model of grammar. Ms., University of Amsterdam.
- Bolozky, S. (1978), Some aspects of Modern Hebrew phonology. In R. Berman, ed., *Modern Hebrew Structure*. University Publishing Projects: Tel Aviv, pp.11-67.
- Booij, G. (1997), Non-derivational phonology meets lexical phonology. In Roca, ed. (1997a), pp.261-88.
- Brame, M. (1974), The cycle in phonology: stress in Palestinian, Maltese, and Spanish. *Linguistic Inquiry* 5:39-60
- Broe, M. (1991), A unification-based approach to prosodic analysis. In Bird, ed. (1991), pp. 27-44.
- Bromberger S. and M. Halle (1989), Why phonology is different. *Linguistic Inquiry* 20:51-70.
- Bromberger, S. and M. Halle (1997), The contents of phonological signs: a comparison between their use in derivational theories and optimality theories. In Roca, ed. (1997a), pp. 93-124.
- Broselow, E. (1976), The Phonology of Egyptian Arabic. Doctoral Dissertation, University of Massachusetts, Amherst.
- Calabrese, A. (1995), A constraint-based theory of phonological markedness and simplification procedures. *Linguistic Inquiry* 26:373-463.
- Carnochan, J. (1960), Vowel harmony in Igbo. *African Language Studies* 1:155-63. Reprinted in F.R. Palmer, ed. (1970), *Prosodic Analysis*. Oxford University Press: London.
- Chen, M. (1970), Vowel length variation as a function of the voicing of the consonant environment. *Phonetica* 15:187-90.
- Chomsky, N. (1957), *Syntactic Structures*. Mouton: The Hague.
- Chomsky, N. (1965), *Aspects of the Theory of Syntax*. MIT Press: Cambridge, Mass..
- Chomsky, N. (1971), Deep structure, surface structure, and semantic interpretation. In L.A. Jakobovits and D.D. Steinberg, eds., *Semantics*, Cambridge University Press: Cambridge, pp.183-216.
- Chomsky, N. (1975), *The Logical Structure of Linguistic Theory*. Plenum Press: New York.
- Chomsky, N. (1995), *The Minimalist Program*. MIT Press: Cambridge, Mass.

- Chomsky, N. (1998), Some observations on economy in generative grammar. In P. Barbosa, D. Fox, P. Hagstrom, M. McGinnis and D. Pesetsky, eds., *Is the Best Good Enough? Optimality and Competition in Syntax*. MIT Press: Cambridge, Mass..
- Chomsky, N. and M. Halle (1968), *The Sound Pattern of English*. Harper and Row: New York.
- Clements, G.N. (1985), The geometry of phonological features. *Phonology Yearbook* 2:225-52.
- Clements, G.N. (1997), Berber syllabification: derivations or constraints? In Roca, ed. (1997a), pp. 289-330.
- Clements, G.N. (2000), In defence of serialism. *The Linguistic Review* 17:181-98.
- Coleman, J. (1995), Declarative lexical phonology. In J. Durand and F. Katamba, eds., *Frontiers of Phonology: Atoms, Structures, Derivations*, Longman: London, pp.333-82.
- Coleman, J. (1998), *Phonological Representations*. Cambridge University Press: Cambridge.
- Coleman, J. and J. Local (1991), The “no crossing constraint” in autosegmental phonology. *Linguistics and Philosophy* 14:295-338.
- Dinnsen, D., L. McGarrity, K. O'Connor and K. Swanson (2000), On the role of sympathy in acquisition. *Language Acquisition* 8:321-61.
- Dresher, B.E. (1981), Abstractness and explanation in phonology. In Hornstein, N. and D. Lightfoot, eds., *Explanation in Linguistics: The Logical Problem of Language Acquisition*. Longman: London.
- Eisner, J. (1997a), Efficient generation in Primitive Optimality Theory. Ms., University of Pennsylvania. Available from Rutgers Optimality Archive, <http://roa.rutgers.edu/>.
- Eisner, J. (1997b), What constraints should OT allow? Ms., University of Pennsylvania. Available from Rutgers Optimality Archive, <http://roa.rutgers.edu/>.
- Ellison, T.M. (1994), Phonological derivation in optimality theory. In *Proceedings of the First Meeting of the ACL Special Interest Group in Computational Phonology*, Association for Computational Linguistics, pp.25-32.
- Firth, J.R. (1948), Sounds and prosodies. *Transactions of the Philological Society*. Reprinted in F.R. Palmer, ed. (1970), *Prosodic Analysis*. Oxford University Press: Oxford, pp.1-26.
- Fourakis, M. and G. Iverson (1984), On the ‘incomplete neutralization’ of German final obstruents. *Phonetica* 41:140-9.
- Frank, R. and G. Satta (1998), Optimality theory and the computational complexity of constraint violability. *Computational Linguistics* 24:307-15.
- Freidin, R. (1997), Chomsky: the minimalist program. *Language* 73:571-82.

- Gelbart, S. (1984), An elementary introduction to the Langlands programme. *Bulletin of the American Mathematical Society* 10:177-219.
- Gick, B. (1999), A gesture-based account of intrusive consonants in English. *Phonology* 16:29-54.
- Ginsberg, M.L., ed. (1987), *Readings in Monotonic Reasoning*. Morgan Kaufman: Los Altos, California.
- Goldsmith, J. (1976), Autosegmental phonology. Doctoral Dissertation, MIT. Distributed by Indiana University Linguistics Club. Also published (1979) by Garland Press: New York.
- Goldsmith, J. (1979), The aims of autosegmental phonology. In D. Dinnsen, ed., *Current Approaches to Phonological Theory*, Indiana University Press: Bloomington, pp.202-22.
- Goldsmith, J. (1990), *Autosegmental and Metrical Phonology*. Blackwell: Cambridge, Mass.
- Goldsmith, J. (1992), A note on the genealogy of research traditions in modern phonology. *Journal of Linguistics* 28:149-63.
- Goldsmith, J. (1993), Harmonic phonology. In Goldsmith, J., ed., *The Last Phonological Rule: Reflections on Constraints and Derivations*, Chicago University Press: Chicago, pp. 21-60.
- Goldsmith, J. (1994), Disentangling autosegments: a response. *Journal of Linguistics* 30:499-507.
- Goldsmith, J. (1995), Phonological theory. In J. Goldsmith, ed., *The Handbook of Phonological Theory*, Blackwell: Oxford, pp.1-23.
- Goldsmith, J. and G. Huck (1995), *Ideology and Linguistic Theory: Noam Chomsky and the Deep Structure Debates*. Routledge: London.
- Hale, K. (1973), Deep-surface canonical disparities in relation to analysis and change: an Australian example. In Sebeok, T., ed., *Current Trends in Linguistics 11*, Mouton: The Hague, pp.401-58.
- Halle, M. (1962), Phonology in generative grammar. *Word* 18:54-72.
- Halle, M. (1983), On distinctive features and their articulatory implementation. *Natural Language and Linguistic Theory* 1:91-105.
- Halle, M. (1995), Comments on Luigi Burzio's The rise of optimality theory. *Glott International* 1(9/10):27-8.
- Halle, M. and G.N. Clements (1983), *Problem Book in Phonology*. MIT Press: Cambridge, Mass..
- Halle, M. and W. Idsardi (1995), General properties of stress and metrical structure. In J. Goldsmith, ed., *The Handbook of Phonological Theory*, Blackwell: Oxford, pp. 403-43.

- Halle, M. and W. Idsardi (1997), *r*, hypercorrection, and the elsewhere condition. In Roca, ed. (1997a), pp.331-48.
- Halle, M. and A. Marantz (1993), Distributive morphology and the pieces of inflection. In K. Hale and S.J. Kayser, eds., *The View From Building 20: Essays in Honor of Sylvain Bromberger*, MIT Press: Cambridge, Mass., pp.111-76.
- Hammond, M. (1988), On deriving the well-formedness condition. *Linguistic Inquiry* 19:319-25.
- Hammond, M. (2000) The logic of optimality theory. Ms., University of Arizona. Available from Rutgers Optimality Archive, <http://roa.rutgers.edu/>.
- Hayes, B. (1989). Compensatory lengthening in moraic phonology. *Linguistic Inquiry* 20:253-306.
- Hayes, B. (1995), *Metrical Stress Theory: Principles and Case Studies*. University of Chicago Press: Chicago.
- Hayes, B. (1999), Phonological restructuring in Yidiny and its theoretical consequences. In B. Hermans and M. van Oostendorp, eds., *The Derivational Residue in Phonological Optimality Theory*, John Benjamins: Amsterdam, pp. 175-205.
- Heck, F., G. Müller, R. Vogel, S. Fischer, S. Vikner and T. Schmid (2002), On the nature of the input in optimality theory. *The Linguistic Review* 19:345-76.
- Howard, I. (1975), Can the 'Elsewhere Condition' get anywhere? *Language* 51:109-27.
- Hualde, J. (1989), Autosegmental and metrical spreading in the vowel-harmony systems of northwestern Spain. *Linguistics* 27:773-805.
- Hyman, L. (1993), Problems for rule ordering in phonology: two Bantu test cases. In J. Goldsmith, ed., *The Last Phonological Rule: Reflections on Constraints and Derivations*, Chicago University Press: Chicago, pp. 21-60.
- Idsardi, W. (1997), Phonological derivations and historical changes in Hebrew spirantisation. In Roca, ed. (1997a), pp. 367-92.
- Idsardi, W. (1998), Tiberian Hebrew spirantisation and phonological derivations. *Linguistic Inquiry* 29:37-73.
- Idsardi, W. (2000), Clarifying opacity. *The Linguistic Review* 17:337-350.
- Inkelas, S. (1994), The consequences of optimization for underspecification. In J. Beckman, ed., *Proceedings of the 25<sup>th</sup> Meeting of the Northeastern Linguistics Society*, pp.287-302.
- Inkelas, S. and C.O. Orgun (1995), Level ordering and economy in the lexical phonology of Turkish. *Language* 71:763-93.

- Inkelas, S., C.O. Orgun and C. Zoll (1997), The implications of lexical exceptions for the nature of grammar. In Roca, ed. (1997a), pp.367-418.
- Itô, J. (1986), Syllable Theory in Prosodic Phonology. Doctoral Dissertation, University of Massachusetts, Amherst. Published (1988) by Garland Press: New York.
- Iverson, G. (1989), On the category supralaryngeal. *Phonology* 6:285-304.
- Iverson, G. (1995), Rule ordering. In J. Goldsmith, ed., *Handbook of Phonological Theory*. Blackwell: Oxford.
- Johansson, S. (1973), Linking and intrusive /r/ in English: a case for a more concrete phonology. *Studia Linguistica* 27:53-68.
- Johnson, C.D. (1972), *Formal Aspects of Phonological Description*. Mouton: The Hague.
- Joos, M. (1942), A phonological dilemma in Canadian English. *Language* 18:141-4.
- Kager, R. (1997), Rhythmic vowel deletion in optimality theory. In Roca, ed. (1997a), pp.463-500.
- Kager, R. (1999), *Optimality Theory*. Cambridge University Press: Cambridge.
- Kahn, D. (1976), Syllable-based Generalizations in English Phonology. Doctoral Dissertation, MIT. Distributed by Indiana University Linguistics Club.
- Kaplan, R.M. and M. Kay (1994), Regular models of phonological rule systems. *Computational Linguistics* 20:331-78.
- Karttunen, L. (1993), Finite-state constraints. In J. Goldsmith, ed., *The Last Phonological Rule: Reflections on Constraints and Derivations*, Chicago University Press: Chicago, pp. 173-94.
- Kay, M. (1979), Functional grammar. *Proceedings of the 5<sup>th</sup> Annual Meeting of the Berkeley Linguistics Society*, pp. 142-58.
- Kaye, J., J. Lowenstamm and J.-R. Vergnaud (1985), The internal structure of phonological elements: a theory of charm and government. *Phonology Yearbook* 2:303-26.
- Kenstowicz, M. (1994), *Phonology in Generative Grammar*. Blackwell: Oxford.
- Kenstowicz, M. and C. Kisseberth (1973), Unmarked bleeding orders. In C. Kisseberth, ed., *Studies in Generative Phonology*, Linguistic Research Inc.: Edmonton, Canada, pp.1-12.
- Kenstowicz, M. and C. Kisseberth (1977), *Topics in Phonological Theory*. Academic Press: New York.
- Kenstowicz, M. and C. Kisseberth (1979), *Generative Phonology: Description and Theory*. Academic Press: New York.

- Kiparsky, P. (1968), Linguistic universals and language change. In E. Bach and R. Harms, eds., *Universals in Linguistic Theory*, Holt, Rinehart and Winston: New York, pp.191-214.
- Kiparsky, P. (1973), "Elsewhere" in phonology. In S. Anderson and P. Kiparsky, eds., *A Festschrift for Morris Halle*, Holt, Rinehart and Winston: New York, pp.93-106.
- Kiparsky, P. (1976), Abstractness, opacity, and global rules. In A. Koutsoudas, ed., *The Application and Ordering of Grammatical Rules*, Mouton: The Hague, pp.41-54.
- Kiparsky, P. (1982), From cyclic to lexical phonology. In H. van der Hulst and N. Smith, eds., *The Structure of Phonological Representations (part I)*, Foris: Dordrecht, pp.131-75.
- Kiparsky, P. and L. Menn (1977), On the acquisition of phonology. In J. McNamara, ed., *Language Learning and Thought*, Academic Press: New York, pp.47-78.
- Kirchner, R. (1996), Synchronic chain shifts in optimality theory. *Linguistic Inquiry* 27:341-50.
- Kisseberth, C. (1970a), On the functional unity of phonological rules. *Linguistic Inquiry* 1:291-306.
- Kisseberth, C. (1970b) Vowel elision in Tonkawa and derivational constraints. In J. Sadock and A. Vanek, eds., *Studies Presented To Robert B. Lees By His Students*, Linguistic Research, Inc.: Edmonton, pp.109-38.
- Kornai, A. (1991), Formal Phonology. Doctoral Dissertation, Stanford University. Published (1994) by Garland Press: New York.
- Kornfilt, J. (1997), *Turkish*. Routledge: London.
- Koskenniemi, K. (1983), Two-Level Morphology: A General Computational Model for Word-Form Recognition and Production. Doctoral Dissertation, University of Helsinki.
- Koutsoudas, A., G. Sanders and C. Noll (1974), The application of phonological rules. *Language* 50:1-28.
- Kurusu, K. (2001), The Phonology of Morpheme Realization. Doctoral Dissertation, University of California, Santa Cruz. Available from Rutgers Optimality Archive, <http://roa.rutgers.edu/>.
- Kuroda, S.-Y. (1967), *Yawelmani Phonology*. MIT Press: Cambridge, Mass..
- Lass, R. (1984), *Phonology: An Introduction to Basic Concepts*. Cambridge University Press: Cambridge.
- Lombardi, L. (2001), Why Place and Voice are different: constraint interactions and feature faithfulness in Optimality Theory. In L. Lombardi, ed., *Segmental Phonology in Optimality Theory: Constraints and Representations*, Cambridge University Press: New York. Available from Rutgers Optimality Archive, <http://roa.rutgers.edu/>.

- Łubowicz, A. (1999), Derived environment effects in OT. In *Proceedings of the West Coast Conference on Formal Linguistics 17*, pp.451-65. Available from Rutgers Optimality Archive, <http://roa.rutgers.edu/>.
- McCarthy, J. (1979), Formal Problems in Semitic Phonology and Morphology. Doctoral Dissertation, MIT. Distributed by Indiana University Linguistics Club. Also published (1985) by Garland Press: New York.
- McCarthy, J. (1986), OCP effects: gemination and anti-gemination. *Linguistic Inquiry* 17:207-63.
- McCarthy, J. (1991), Synchronic rule inversion. In *Proceedings of the 17<sup>th</sup> Annual Meeting of the Berkeley Linguistics Society*, pp.192-207.
- McCarthy, J. (1993a), A case of surface constraint violation. *Canadian Journal of Linguistics* 38:169-95.
- McCarthy, J. (1993b), The parallel advantage: containment, consistency, and alignment. Ms., University of Massachusetts, Amherst.
- McCarthy, J. (1999a), Sympathy and phonological opacity. *Phonology* 16:331-99.
- McCarthy, J. (1999b), Review of Iggy Roca (ed.) (1997) *Derivations and Constraints in Phonology*. *Phonology* 16:265-71.
- McCarthy, J. (1999c), Appendix: note on Boston *r* and the elsewhere condition. Appendix to McCarthy (1999b), University of Massachusetts, Amherst. Available from <http://www-unix.oit.umass.edu/~jjmccart/appendix.pdf>
- McCarthy, J. (2000), Harmonic serialism and parallelism. In *Proceedings of the 30<sup>th</sup> Annual Meeting of the Northeastern Linguistics Society*, pp.501-24.
- McCarthy, J. (2002), *A Thematic Guide to Optimality Theory*. Cambridge University Press: Cambridge.
- McCarthy, J. (2002b), Against gradience. Ms., University of Massachusetts, Amherst. Available from Rutgers Optimality Archive, <http://roa.rutgers.edu/>.
- McCarthy, J. (2003), Sympathy, cumulativity, and the Duke-of-York gambit. In C. Féry and R. van de Vijver, eds., *The Syllable in Optimality Theory*, Cambridge University Press: New York.
- McCarthy, J. and A. Prince (1993a), Generalized alignment. In G. Booij and J. van Marle, eds., *Yearbook of Morphology*, Kluwer: Dordrecht, pp.79-153.
- McCarthy, J. and A. Prince (1993b), Prosodic Morphology I: Constraint Interaction and Satisfaction. Technical Report 3, Rutgers University Centre for Cognitive Science: New Brunswick, New Jersey.

- McCarthy, J. and A. Prince (1994), The emergence of the unmarked. In *Proceedings of the 24<sup>th</sup> Annual Meeting of the Northeastern Linguistics Society*, pp.333-79.
- McCarthy, J. and A. Prince (1995), Faithfulness and reduplicative identity. In J. Beckman, L.W. Dickey, and S. Urbanczyk, eds., *University of Massachusetts Occasional Papers in Linguistics 18*, pp.249-384. Graduate Linguistics Students Association, University of Massachusetts, Amherst.
- McMahon, A., P. Foulkes and L. Tollfree (1994), Gestural representation and lexical phonology. *Phonology* 11:277-316.
- Mester, R.A. (1986), *Studies in Tier Structure*. Doctoral Dissertation, University of Massachusetts at Amherst. Distributed by Graduate Linguistics Students Association: University of Massachusetts, Amherst.
- Moreton, E. (1999), Non-computable functions in optimality theory. Ms., University of Massachusetts, Amherst. Available from Rutgers Optimality Archive, <http://roa.rutgers.edu/>.
- Myers, S. (1991), Persistent rules. *Linguistic Inquiry* 22:315-44.
- Myers, S. (1997a), OCP effects in optimality theory. *Natural Language and Linguistic Theory* 15:847-92.
- Myers, S. (1997b), Expressing phonetic naturalness in phonology. In Roca, ed. (1997a), pp.125-52.
- Newman, S. (1944), *Yokuts Language of California*. Viking Fund: New York.
- Norton, R. (1998), Optimality theory without Gen. In *Essex Graduate Student Papers in Language and Linguistics* 2:19-30.
- Noyer, R. (1997), Attic Greek accentuation and intermediate derivational representations. In Roca, ed. (1997a), pp.501-28.
- Ogden, R. and J. Local (1994), Disentangling autosegments and prosodies: a note on the misrepresentation of a research tradition in phonology. *Journal of Linguistics* 30:477-498.
- Orgun, C.O. and R. Sprouse (1999), From MPARSE to CONTROL: deriving ungrammaticality. *Phonology* 16:191-220.
- Paradis, C. (1988), On constraints and repair strategies. *The Linguistic Review* 6:71-97.
- Paradis, C. (1996), The inadequacy of faithfulness and filters in loanword adaptation. In J. Durand and B. Laks, eds., *Current Trends in Phonology: Models and Methods Volume 2*, Salford University Press: Salford, pp.509-34.
- Paradis, C. (1997), Non-transparent constraint effects in Gere: from cycles to derivations. In Roca, ed. (1997a), pp.529-550.

- Partee, B.H., A. ter Meulen and R. Wall (1990), *Mathematical Methods in Linguistics*. Kluwer: Dordrecht.
- Port, R. and P. Crawford (1989), Incomplete neutralization and pragmatics in German. *Journal of Phonetics* 17:257-82.
- Prince, A. (1997a), Endogenous constraints on optimality theory. Handout of paper presented to Maryland Mayfest 97 workshop, Johns Hopkins University, Baltimore, Maryland.
- Prince, A. (1997b), Elsewhere and otherwise. Expanded version of a letter in *Glott International* 2(6):1,23-4, available from Rutgers Optimality Archive, <http://roa.rutgers.edu/>.
- Prince, A. (2002), Entailed ranking arguments. Ms., Rutgers University, New Brunswick. Available from Rutgers Optimality Archive, <http://roa.rutgers.edu/>.
- Prince, A. and P. Smolensky (1993), Optimality Theory: Constraint Interaction in Generative Grammar. Technical Report 2, Rutgers University Centre for Cognitive Science: New Brunswick. Corrected version (2002) available from Rutgers Optimality Archive, <http://roa.rutgers.edu/>.
- Pulleyblank, D. and W. Turkel (1997), Gradient retreat. In Roca, ed. (1997a), pp. 153-93.
- Pullum, G. (1976), The Duke of York gambit. *Journal of Linguistics* 12:83-102.
- Pullum, G. (1979), *Rule Interaction and the Organization of a Grammar*. Garland Publishing: New York.
- Ringen, C. (1976), Vacuous application, iterative application, reapplication, and the unordered rule hypothesis. In A. Koutsoudas, ed., *The Application and Ordering of Grammatical Rules*, Mouton: The Hague.
- Roca, I. (1994), *Generative Phonology*. Routledge: London.
- Roca, I., ed. (1997a), *Derivations and Constraints in Phonology*. Clarendon Press: Oxford.
- Roca, I. (1997b), Derivations or constraints, or derivations and constraints? In Roca, ed. (1997a), pp.3-42.
- Roca, I. (1997c), There are no “glides”, at least in Spanish: an optimality account. *Probus* 9:233-65.
- Roca, I. and W. Johnson (1999), *A Course in Phonology*. Blackwell: Oxford.
- Rosenthal, S. (1994), Vowel Glide Alternation in a Theory of Constraint Interaction. Doctoral Dissertation, University of Massachusetts, Amherst.
- Rubach, J. (1984), *Cyclic and Lexical Phonology: The Structure of Polish*. Foris: Dordrecht.

- Rubach, J. (1993), *The Lexical Phonology of Slovak*. Oxford University Press: Oxford.
- Rubach, J. (1997), Extrasyllabic consonants in Polish: derivational optimality theory. In Roca, ed. (1997a). pp.551-81.
- Rubach, J. (2000), Glide and glottal stop insertion in Slavic languages: a DOT analysis. *Linguistic Inquiry* 31:271-317.
- Russell, K. (1997), Optimality theory and morphology. In Archangeli and Langendoen, eds. (1997), pp.102-133.
- Sagey, E. (1988), On the ill-formedness of crossing association lines. *Linguistic Inquiry* 19:109-18.
- Samek-Lodivici, V. and A. Prince (1999), Optima. Ms., University of London and Rutgers University, New Brunswick. Available from Rutgers Optimality Archive, <http://roa.rutgers.edu/>.
- Sapir, E. (1933), The psychological reality of phonemes. Originally published in French in *Journal de Psychologie Normale et Pathologique* 30:247-65. English translation appears in D. Mandelbaum, ed. (1949), *Selected Writings of Edward Sapir in Language, Culture and Personality*. University of California Press: Berkeley.
- Sapir, E. and M. Swadesh (1978), *Nootka Texts: Tales and Ethnological Narratives, with Grammatical Notes and Lexical Material*. AMS Press: New York.
- Schein, B. and D. Steriade (1986), On geminates. *Linguistic Inquiry* 17:691-744.
- Scobbie, J. (1991), Towards declarative phonology. In Bird, ed. (1991), pp. 1-26.
- Scobbie, J., J. Coleman and S. Bird (1997), Key aspects of declarative phonology. In J. Durand and B. Laks, eds., *Current Trends in Phonology: Models and Methods Volume 2*, Salford University Press: Salford, pp.685-710.
- Shibitani, M. (1973), The rule of surface phonetic constraints in generative phonology. *Language* 49:87-106.
- Singh, R. (1987), Well-formedness conditions and phonological theory. In W. Dressler, ed., *Phonologica 1984*, Cambridge University Press: Cambridge, pp.273-85.
- Smolensky, P. (1997), Constraint interaction in generative grammar II: local conjunction, or random rules in Universal Grammar. Handout, Maryland Mayfest 97 workshop, Johns Hopkins University, Baltimore, Maryland.
- Soames, S. (1974), Rule orderings, obligatory transformations, and derivational constraints. *Theoretical Linguistics* 1:116-38.
- Sommerstein, A. (1974), On phonotactically motivated rules. *Journal of Linguistics* 10:71-94.

- Sprouse, R., S. Inkelas, and C.O. Orgun (2001), Lexical representation as definition: handling opacity in two-level OT. Ms., University of California at Berkeley and at Davis.
- Steriade, D. (1986), Yokuts and the vowel plane. *Linguistic Inquiry* 17:129-46.
- Tesar, B. (1995), Computational Optimality Theory. Doctoral Dissertation, University of Colorado, Boulder. Available from Rutgers Optimality Archive, <http://roa.rutgers.edu/>.
- Twaddell, W.F. (1935), On defining the phoneme. *Language Monographs* 16: Linguistic Society of America. Reprinted in M. Joos, ed., *Readings in Linguistics I*. Chicago University Press: Chicago, pp.55-79.
- Waksler, R. (1986), CV- versus X-notation: a formal comparison. In *Proceedings of the 12<sup>th</sup> Annual Meeting of the Berkeley Linguistics Society*, pp.271-83.
- Walli-Sagey, E. (1986), On the representation of complex segments and their formation in Kinyarwanda. In L. Wetzels and E. Sezer, eds., *Studies in Compensatory Lengthening*, Dordrecht: Foris, pp. 251-95.
- Wheeler, D. and D. Touretzky (1993), A connectionist implementation of cognitive phonology. In J. Goldsmith, ed., *The Last Phonological Rule*, University of Chicago Press: Chicago, pp.146-72.
- Yip, M. (1988), The obligatory contour principle and phonological rules: a loss of identity. *Linguistic Inquiry* 19:65-100.
- Zaharani Ahmad (1998), Phonology and Morphology Interface in Malay: An Optimality Theoretic Account. Doctoral Dissertation, University of Essex.
- Zetterstrand, S. (1996), A formal comparison of two models of vowel height. Abstract, Harvard University, Cambridge, Mass..
- Zimmer, K. (1975), Some thoughts on likely phonologies for non-ideal speakers. In R. Grossman, L.J. San and T. Vance, eds., *Papers from the Parasession on Functionalism*, Chicago Linguistic Society, pp.556-67.
- Zoll, C. (1995), Consonant mutation in Bantu. *Linguistic Inquiry* 26:536-45.
- Zoll, C. (1998), *Parsing Below The Segment in a Constraint-based Framework*. Centre for the Study of Language and Information: Stanford, California.
- Zwicky, A. (1974), Taking a false step. *Language* 50:215-24.
- Zwicky, A. (1986), The general case: basic form versus default form. In *Proceedings of the 12<sup>th</sup> Annual Meeting of the Berkeley Linguistics Society*, pp.305-14.