DECLARATIVE PHONOLOGY

Steven Bird, John Coleman, Janet Pierrehumbert and James Scobbie

University of Edinburgh, AT&T Bell Laboratories,
Northwestern University, Stanford University

1 Introduction

Declarative phonology is a program of research that was motivated in part by the need for theories of phonology that can be implemented on a computer. While it is clear that such a development would be beneficial for both theoretical and field phonology, it is not immediately obvious how one should go about implementing phonological models. The so-called 'declarative' approach draws on a key insight from theoretical computer science, where there has been a long tradition of distinguishing between the *declaration* of a problem and a *procedure* which computes the solution to that problem. Paradoxically, the kind of problem specifications that are frequently the most useful for computational implementation are those which make the fewest procedural commitments.

The declarative phonology programme is, at its heart, an attempt to do away with the ordered derivations and the concomitant feature-changing rules of traditional generative phonology. In this respect, declarative phonology ties in with some recent developments in theoretical phonology where feature-changing rules have been criticized or explicitly avoided (Rice, 1989; McCarthy, 1991). However, it is also possible to find precedents in the literature on American Structuralist phonemic phonology (Hockett, 1954), Firthian Prosodic Phonology, Natural Generative Phonology (Hooper, 1976; Hudson, 1980) and Montague Phonology (Wheeler, 1981; Bach, 1983). More recently, 'harmonic' approaches to phonology arising from work in connectionism (Smolensky, 1986) have also questioned the procedural paradigm but from a perspective which does not clearly differentiate the declaration of grammar from the means of its implementation (Goldsmith, ta; Prince & Smolensky, 1992). Despite this difference, the declarative and connectionist approaches are alike as regards their incorporation of various kinds of constraint satisfaction.

With increasing interest in the interaction between phonology and syntax being expressed in the literature, declarative phonology has something to contribute here too. Constraint-based grammar frameworks such as HPSG (Pollard & Sag, 1987) (manifesting good linguistic coverage and attractive computational properties) have the same metatheoretical commitments as declarative phonology. The prospect for having a computational theory of phonology that is fully integrated with a computational theory of syntax and semantics is now imminent.

A final area of concern is the phonology-phonetics interface. In the declarative framework it makes sense to view the relationship between phonology and phonetics as being one of *denotation*. Under this view, phonological representations are *descriptions* of phonetic reality and a particular phonological construct is said to *denote* a phonetic event (Bird & Klein, 1990; Pierrehumbert, 1990; Scobbie, 1991a; Coleman, 1992).

This article consists of four sections, where each section has been contributed by a different author. The first three sections present reanalyses of phenomena that have previously been thought to require the ability to destructively modify phonological structures. In §2, James Scobbie discusses syllabification in Tashlhiyt Berber and presents a declarative analysis couched in a feature-structure based framework. In §3, Steven Bird investigates vowel harmony in Montañes Spanish and consonant harmony in Chumash and proposes a non-feature-changing account using a finite-state model. In §4, John Coleman presents a brief overview of his reconstruction of Lexical Phonology in a declarative framework. The final section contains a commentary by Janet Pierrehumbert, discussing the achievements and prospects of declarative phonology in relation to generative phonology, Lexical Phonology and laboratory phonology.

2 CONSTRAINT CONFLICT (James M. Scobbie)

2.1 The Phonotactic: General Tendency or Hard Constraint?

It is well-known that rewrite rules fail to capture some generalisations about the level of representation they derive (Kisseberth, 1970; Shibatani, 1973). Defining the well-formed structures of that level using phonotactics enables those patterns to be addressed. Moreover, insofar as the patterns that exist in a language trigger its alternations, the alternations are explained.

If well-formedness constraints are used, it is necessary to decide whether or not to use rewrite rules also. When a grammar employs both formal techniques, their interaction is necessarily an area of concern (Scobbie, 1991b). Some work (e.g. (Singh, 1987; Paradis, 1988)) replaces structural descriptions with phonotactics and structural changes with *repair-strategies*. Whenever a structure known to be ill-formed at the surface level of representation can be generated during the derivation, it is indeed generated, only to be destructively modified. Therefore one can state general *tendencies* of distribution directly in the grammar and 'repair' those forms generated by the tendency which happen to be in conflict with empirical considerations. Though in these theories phonological representations are intended to be models of aspects of competence, the derivation and the intermediate forms are uninterpreted aspects of the theory. Such hidden elements imbue the theory with greater abstractness, and they decrease the modularity of the theory with respect to the procedures that can be employed to implement it.

Another line of research is to use only constraints acting in consort to describe a level of representation. If the constraints are broad-stroke general tendencies (such as a syllable's disdain for a coda or love of an onset) they will of course sometimes clash in their demands. Some means must be found of resolving such inconsistencies.

We can avoid an inconsistent grammar by using formal statements of distribution which fail to clash by virtue of their precision, and by using familiar conventions such as the Elsewhere Condition. Formalising the universal tendencies with an appropriate amount of detail dispels constraint conflict. The interaction of these *hard constraints* is therefore declarative and compositional. This is the approach advocated here.

Other approaches adopt optimisation techniques which provide a metric capable of determining the best-formed structures possible in the contradictory circumstances. The optimal solution the one in which the fewest *important* constraints are violated. Tendencies are in fact *soft constraints* in these theories and are carefully prioritised in a derivational architecture familiar from connectionism.

In the next section I examine data which has been argued to be ideally suited to optimisation. I will show that once the tendencies are formalised, they include enough detail to allow them to be implemented as hard constraints in a derivationally neutral, declarative way.

2.2 Tashlhiyt Berber syllabification

The nature of syllabification usually allows phonotactics to easily discriminate between well-formed and ill-formed syllables. The syllable structure of Berber (Tashlhiyt dialect), however, provides a challenge for standard approaches to syllabification because any segment in the language can be syllabic (Dell & El-Medlaoui, 1985). Consequently the number of absolute constraints on a syllable's form are small, as evidenced by such forms as /tf̩.tk̩t/ 'you suffered a sprain'. The syllabifications found are predictable, however:

3-MASC-SNG	3-FEM-SNG	
/i̩ldi̩/	/tl̩di̩/	pull
/i̩ɣza̩/	/tɣ̩za̩/	dig
2-SNG-PERF	3-FEM-SNG-PERF	
/ts̩kr̩t/	/ts̩kra̩s	do
/tn̩šf̩t/	/tn̩šfa̩s/	graze (of skin)
/tx̩zn̩t/	/txz̩na̩s	store

If any consonant can be syllabic, what constraints can we impose on possible syllable structure? Are these constraints parametric variants of general tendencies? Do they require optimisation to resolve conflicts?

To handle Berber, Dell and El-Medlaoui suggest a syllabification algorithm which is unlike that needed for other languages. It sweeps for segments of a given sonority from left to right, and builds core CV syllables on them, with the targeted segment being the nucleus. The first sweep is for the most sonorous group, /a/. Further sweeps target decreasingly sonorous classes:

a, High-Vocoid, liquid, nasal, voiced fricative, v-less fric., voiced stop, v-less stop.

Any unsyllabified segment left over is a coda. Thus

/tzdmt/ → /tz(dm̩)t/ → /(tz̩)(dm̩)t/ → /(tz̩)(dm̩t)/

Prince & Smolensky (1992:hereafter P&S) propose an analysis intended to be more in keeping with universal syllabification. They incorporate such universal tendencies as 'syllables must have onsets', 'nuclei must be maximally sonorous' and 'each segment must be syllabified'. Of course, statements of such generality conflict: in /i̩ldi̩/ the initial syllable has no onset; in /ts̩kr̩t/ the nucleus /s/ is far from sonorous.

To resolve the constraint conflict, P&S offer a theory of optimisation in which constraints are ranked for value. Given C_1 and C_2 where C_1 is higher valued than C_2, if these constraints clash, it is C_1 which must be obeyed. Surface forms which violate some constraints (the less important ones) are permitted. Constraints are defeasible, conflicting and ranked in that it is their place in the prioritisation hierarchy which determines whether they are likely to be over-ridden. (This is somewhat like the rules applying early in a procedural derivation that produce forms which are input to feature-changing rules.)

One of the problems with such an analysis is that different formalisations of tendencies as general as ‘nuclei must be maximally sonorous’ are possible, and the very formulation will affect the ranking of the constraints. P&S give for Berber:

$$\begin{array}{c}\text{Nuc}\\ | \\ \text{/a/}\end{array} > PARSE > ONS > FILL > H.nuc > \neg CODA$$

These mean (in order or decreasing priority): /a/ must be a nucleus, all underliers must be syllabified, syllables have onsets, syllable roles must be filled, nuclei must be maximally sonorous, syllables have no codas.

The analysis works roughly as follows. Given /txznt/, if the most sonorous segments /n/ and /z/ were to be nuclei, the syllable with /n/ as nucleus would have no onset. This breaks a higher-ranked constraint (ONS) than the constraint about nuclei being maximally sonorous (H.nuc). Contrast this surface form with /tx̩.zn̩t/. Syllabic /x/ violates H.nuc but the string conforms to ONS. The latter is optimal, so is chosen as the surface form.

Optimality is required because P&S have reified tendencies as constraints on derivations. But if we express the language-specific variation in these tendencies by adding explicit information to the tendencies, we can avoid prioritising them (a language-particular process itself). Of course, it is incumbent on any theory to make its rules formal and to incorporate the idiosyncracies around the edges of the general patterns, so if the rules proposed here look complex compared to those of P&S, note that first, they express a more detailed level of analysis and second, they are modifications of highly general rules. The ways in which these constraints interact with each other is hard-wired. Each one is surface-true rather than being dependent on its place in a bank of rules to gain its meaning (with the possible exception of the elsewhere-ordered 6a/6b).

The formalisations of the appropriate rules are as follows. (The papers referenced above give an introduction to the formal mechnisms, but note that co-syllabic structures share the value of their σ attribute, where sharing is indicated by tag: $\boxed{1}$.) (1a) says a syllable can be peripheral or non-peripheral and that the peripheral type of syllable is final in its domain. (1b) assigns the normal syllable functions and an extra appendix to peripheral syllables. (1) uses an unfamilar type of constraint, the *sort assignment*, but the point is that these statements encode final extrametricality. (2) demands that each segment be dominated by syllable structure, like PARSE. (3) imposes a sonority minimum, that /a/ be a nucleus. (4) is like H.nuc in that it forces codas to be no more sonorous than onsets. (5) deals with phrase-final phenomena — e.g. nuclear stops must be phrase-internal. (6) expresses ONS and FILL and ¬CODA and H.nuc: the pre-nuclear segment must fill the onset, and in the general case the onset will be less sonorous. The onset can be more sonorous — the specific case (6b) — just in case it follows an open syllable.

1a. *syllable* = *peripheral* ∨ *non-periph*. *non-periph* $\prec_{prec}$ *peripheral*

1b. *syllable*: ONSET & NUCLEUS & CODA. *peripheral*: APPENDIX

2. $\boxed{1}\, segment\,[\ ] \;\rightarrow\; [\sigma \ldots \boxed{1}]$

3a. $\left[\text{SEGMENT}\,\boxed{1}\,[/a/]\right] \;\rightarrow\; \left[\begin{array}{l}\text{SEGMENT}\,\boxed{1}\\ \sigma|\text{NUCLEUS}\,\boxed{1}\end{array}\right]$

3b. $\{p, \ldots\} \prec_{son} \cdots \prec_{son} \{i, u\} \prec_{son} \{a\}$

4. $\left[\sigma \left[\begin{array}{l}\text{NUCLEUS}\,\boxed{1}\\ \text{CODA}\,\boxed{2}\end{array}\right]\right] \rightarrow \boxed{2} \preceq_{son} \boxed{1}$

5a. $\begin{bmatrix} \text{SEGMENT}\ \boxed{1}\ obs\,[\cdots[cont-]] \\ \sigma|\text{NUCLEUS}\ \boxed{1} \end{bmatrix}_i \rightarrow [\phi\,\boxed{2}]_i\,[\phi\,\boxed{2}]$

5b. (Opt) $\begin{bmatrix} \text{SEGMENT}\ \boxed{1}\ cons[\,] \\ \sigma|\text{NUCLEUS}\ \boxed{1} \end{bmatrix}_i \rightarrow [\phi\,\boxed{2}]_i\,[\phi\,\boxed{2}]$

6a. $[\ ]\ \begin{bmatrix} \text{SEG}\ \boxed{1} \\ \sigma|\text{NUC}\ \boxed{1} \end{bmatrix} \rightarrow \begin{bmatrix} \text{SEG}\ \boxed{2} \\ \sigma\ \boxed{3} \end{bmatrix} \begin{bmatrix} \text{SEG}\ \boxed{1} \\ \sigma\ \boxed{3} \begin{bmatrix} \text{NUC}\ \boxed{1} \\ \text{ONS}\ \boxed{2} \end{bmatrix} \end{bmatrix}$

6b. $[\text{SEG}\ \boxed{1}]\ \begin{bmatrix} \text{SEG}\ \boxed{2} \\ \sigma|\text{NUC}\ \boxed{2} \end{bmatrix}_i \rightarrow \begin{bmatrix} \text{SEG}\ \boxed{4} \\ \sigma|\text{NUC}\ \boxed{4} \end{bmatrix} \begin{bmatrix} \text{SEG}\ \boxed{1} \\ \sigma\ \boxed{3} \end{bmatrix} \begin{bmatrix} \text{SEG}\ \boxed{2} \\ \sigma\ \boxed{3} \begin{bmatrix} \text{NUC}\ \boxed{2} \\ \text{ONS}\ \boxed{1} \end{bmatrix} \end{bmatrix}_i$

where $\boxed{2} \prec_{son} \boxed{1}$

The analysis is couched in terms of Attribute Value Phonology (Scobbie, 1991a). Note that, to be syllabified, the value of the SEGMENT attribute is shared by the value of one of the following paths:

$$[\sigma|\text{ONSET}],\ [\sigma|\text{NUCLEUS}],\ [\sigma|\text{CODA}],\ [\sigma|\text{APPENDIX}]$$

All of these routes linking segments to σ satisfy the demands of prosodic licensing in (2) (see (Scobbie, 1992) for more discussion).

The core of the analysis is found in the constraints of (6). Assuming that every syllable must have nucleus filled with segmental material, there are a number of apparently possible nuclei in a string such as /ildi/ given that all segments may be nuclear. The constraints will rule all such choices as ill-formed, however, bar one. For example, ∗ /il̩.di̩/ is bad because /l/'s onset, which is more sonorous than /l/, is not preceded by an open syllable (6b). /i̩l.di̩/ is well-formed because it satisifes every constraint. The fact that phrase-initial syllables can be onsetless is encoded in the form of (6a) rather than by introducing a soft constraint placed high in the optimisation hierarchy.

/tl̩.di̩/, which is also well-formed, has the initial syllable (tl̩) rather than (t̩) or (t̩l) because /l/ is more sonorous than /t/. In the context of this word, /l/ cannot be /t/'s coda, and it cannot be the onset to a syllable of its own — (ld̩) or (ld̩i) — because first /i/ cannot be a coda to /d/ (4) and second there would be no onset to /i/'s syllable (6b).

/txzmt/ is analysed as follows. Initial /t/ as nucleus passes (6), but demands that either /x/ or /z/ be nuclear. (4) rules out the latter possibility and the former would result in other violations such as ∗ /t̩.xz̩mt/ (bad because /m/ is in the coda of nuclear /z/), ∗ /t̩.xz̩.m̩t/ (6), ∗ /t̩.xz̩.mt̩/ (5a). Whatever procedure is used, /tx̩.zm̩t/ emerges as the well-formed syllabification.

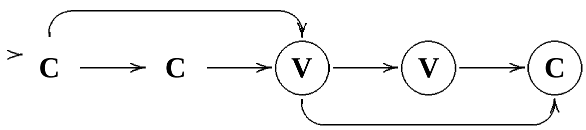
2.3 Conclusion

It will be interesting to investigate the relationship between core formalisations of general cross-linguistic tendencies and the variant constraints permitted by individual grammars. This analysis suggests that hard constraints have their interactions 'pre-compiled' and thereby obviate the need for optimisation to compute relative well-formedness.

3 FEATURE-CHANGING HARMONY (Steven Bird)

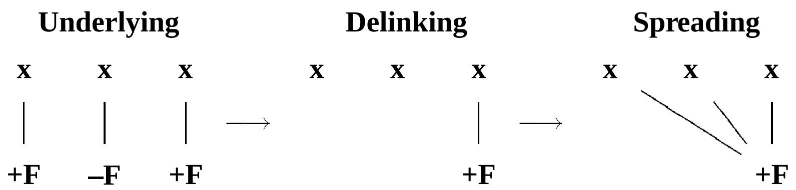
A key challenge for declarative phonology is to come up with analyses of phenomena that are claimed to involve modifying the values of distinctive features. In this section two 'feature-changing' harmonies are considered, and it is shown how they can be analyzed without changing feature values.

The analysis will be expressed in terms of a computational device known as a *finite-state automaton*. Many phonologists will be familiar with the regular expression notation used for stating syllable canons, e.g. **C(C)V(V)(C)**. This can be written as an automaton as follows:



The start state is marked with a '>' sign and the final states are circled. An automaton *accepts* any string that can be generated by proceeding from a start state and following arrows until a final state is reached, where the state reached after n steps must be non-distinct from the n'th element of the string. As it happens any regular expression can be written as an automaton. Two operations on automata are concatenation and intersection. If the automata A_1 and A_2 accept the string sets S_1 and S_2 respectively, then the concatenation of A_1 and A_2 accepts all strings that result from concatenating a member of S_1 with a member of S_2. The *intersection* of A_1 and A_2 accepts the string set $S_1 \cap S_2$. Intersection is the method used to combine multiple interacting constraints on a segment string. More detail about automata for phonology is given by Bird (1992) and Bird & Ellison (1992).

Feature-changing harmony is considered to be an extremely rare phenomenon, the cases of Montañes and Chumash being the only ones I am aware of (Lieber (1987:145) claims to only be aware of the latter). In both cases, the conditioning segment is at the right-hand end of the harmony domain. The analyses of Montañes (McCarthy, 1984) and Chumash (Lieber, 1987) proceed according to the following schema:



Each harmonizing segment is lexically specified with a value of the harmony feature, and then post-lexically all but one of these specifications is removed. A spreading rule then fills in the values as required. (McCarthy identifies the deletion rule as the harmony rule in this case, although it seems to have little in common with ordinary harmony rules.) Lieber (1987:145) claims that "because feature changing harmony requires a rather powerful sort of Delinking rule, it is surely a highly marked sort of process." It is also possible to complain that an analysis where most lexical associations are deleted is overly circuitous and makes it difficult to identify the separate contributions of morphology and phonology to the harmony. In the following two sections the data and new analyses for Montañes and Chumash harmony are presented.

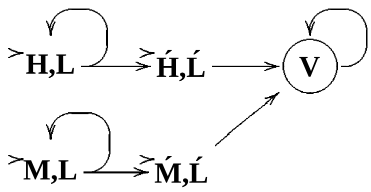
3.1 Montañes Vowel Harmony

McCarthy (1984) presents data from the Pasiego dialect of Montañes Spanish and observes that the non-low vowels of verb roots must agree in height with the stressed vowel in the suffix. Low vowels are transparent to this process.

sEnt- *feel*	sintáis *2pl pr sub*	sentémus *1pl pr ind*	sintí:s *2pl pr ind*
bEb- *drink*	bebámus *1pl pr sub*	bebémus *1pl pr ind*	bibí:s *2pl pr ind*

In the first column of data the stressed vowel is **a** and no harmony occurs; the root vowels are evidently in their 'underlying' forms. In the second and third columns the stressed vowel the root vowels agree with the stressed vowel on their specification of the feature **[high]**. Therefore, underlying high vowels can be changed to mid and underlying mid vowels can be changed to high, and the harmony requires a feature changing rule (as McCarthy also claims, p.304).

The declarative generalisation about this data is the following: if the stressed vowel of the suffix is low then the harmony value of the root is determined morphologically, otherwise it is determined phonologically (by a harmony constraint). This constraint is expressed as the following automaton (ignoring intervening consonants):



In this automaton, V={a,e,i,o,u}, H={i,u}, M={e,o}, L={a}, $\acute{H}$={í,ú}, $\acute{M}$={é,ó}, $\acute{L}$={á}. The automaton states that we can have either a string of high vowels (with low vowels interspersed) ending in a stressed high vowel or a stressed low vowel, or a string of mid vowels (again with low vowels interspersed) ending in a stressed mid vowel or a stressed low vowel. After the stressed vowel there is no constraint on the following material. The three suffix types (áis/ámus, émus, í:s) are specified as follows:

áis/ámus $\begin{bmatrix}\text{PHON} & \acute{\mathbf{L}}\mathbf{H}\end{bmatrix}$ **émus** $\begin{bmatrix}\text{PHON} & \acute{\mathbf{M}}\mathbf{H}\end{bmatrix}$ **í:s** $\begin{bmatrix}\text{PHON} & \acute{\mathbf{H}}\mathbf{H}\end{bmatrix}$

The roots **sEnt** and **bEb** are specified as follows, using the notation for subcategorisation of HPSG (Pollard & Sag, 1987).

sEnt

$$\begin{bmatrix}\text{PHON} & \{\mathbf{H}, \mathbf{V}\}_{x} \\ \text{SYN}|\text{SUBCAT} & \begin{bmatrix}\text{PHON} & \left\{\acute{\mathbf{L}}\mathbf{V.}^{\star}, \bar{\acute{\mathbf{L}}}\mathbf{V}^{\star}\right\}_{x}\end{bmatrix}\end{bmatrix}$$

bEb

$$\begin{bmatrix}\text{PHON} & \{\mathbf{M}, \mathbf{V}\}_{x} \\ \text{SYN}|\text{SUBCAT} & \begin{bmatrix}\text{PHON} & \left\{\acute{\mathbf{L}}\mathbf{V}^{\star}, \bar{\acute{\mathbf{L}}}\mathbf{V}^{\star}\right\}_{x}\end{bmatrix}\end{bmatrix}$$

These feature structures introduce a formal device known as 'parallel disjunction'.

When disjunctions $\{m, n\}_x$ and $\{p, q\}_x$ are coindexed in this way it means that m can be chosen iff p is chosen and n can be chosen iff q is chosen. Consider the structure on the left for **sEnt**. It has a high vowel if its suffix has a low vowel, and it does not specify vowel height if its suffix has a nonlow vowel (a generalisation which does not arise transparently out of the feature-changing analysis). The root **bEb** is identical except that it has a mid vowel if its suffix has a low vowel. If we combine **sEnt** with the three suffixes and apply the harmony rule, the following feature structures are produced.

sintáis	**sentémus**	**sintí:s**
[PHON **HĹH**]	[PHON **MḾH**]	[PHON **HH́H**]

A potential problem with this analysis is that it makes use of a kind of subcategorisation that is sensitive to phonology, and this is not permitted in the most recent version of HPSG. Since the subcategorisation is dependent upon the immediately following segment (on the vowel plane), it is possible to localise this contextual information in the phonology attribute using a technique described by Bird (1992), thereby obviating the need for phonologically-sensitive subcategorisation. An advantage of this analysis over the feature-changing analysis is that the lexical entries of the verb roots clearly show under what conditions the height value is morphologically determined and under what conditions it is phonologically determined.

3.2 Chumash Sibilant Harmony

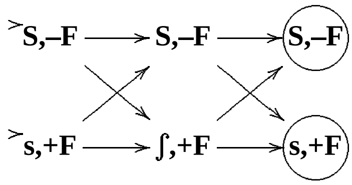
Poser (1982) and Lieber (1987) have presented a rather different kind of harmony which both claim to be feature-changing. The data is from the extinct Hokan language Chumash.

ʃapitʃ^{h}olit	/s + api + tʃ^{h}o + it/	I have a stroke of good luck
sapits^{h}olus	/s + api + tʃ^{h}o + us/	He has a stroke of good luck
ʃapitʃ^{h}oluʃwaʃ	/s + api + tʃ^{h}o + us + waʃ/	He has had a stroke of good luck

Observe that the rightmost sibilant determines the harmony value of all other sibilants of the word and that the same morpheme can both condition and undergo the harmony. Following Lieber, I shall assume the harmonizing feature is [dist(ributed)]. We cannot simply leave sibilants unspecified for [dist] since this feature actually conditions the harmony. If sibilants are specified for [dist] then feature-changing is necessary. The declarative generalisation is that a sibilant is only specified for [dist] if it is final. This condition is encoded into the representation of a segment (in a way that is reminiscent of the lexicalisation of syntactic rules in HPSG). Working with a sibilant tier, we let S={s,ʃ} and adopt a diacritic feature F(inality). The s-default and ʃ-default morphemes are represented as follows:

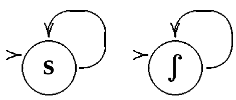
s-default **ʃ-default**

Now the automaton for **sapits^{h}olus** will initially look like the following, once concatenation has taken place.

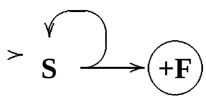


Observe that there are many ways of getting from a start state to a final state. This automaton must be intersected with an automaton for harmony and an automaton for the F(inality) feature. These automata will be part of the definition of a word in terms of the lexical hierarchy of HPSG (Bird, 1992).

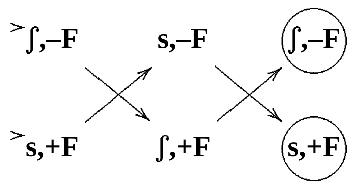
Harmony Automaton



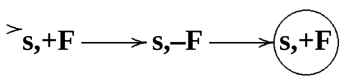
Finality Automaton



Intersecting the lexical form of **sapits^{h}olus** with the harmony automaton gives:



Observe that in the top row, the underspecified sibilants have now been completely specified. Furthermore, there is now no way to get from an **s** to an ʃ or vice versa. There are now only two ways to progress from a start state to a final state, one involving only **s** segments and the other involving only ʃ segments. Intersecting this automaton with the finality automaton gives:



Here, the finality automaton effectively rules out one of the paths, leaving the one which ends in a +F specification. The resulting choice of **s** instead of ʃ is what we required for **sapits^{h}olus**.

4 A Declarative Approach to the Phonology of the Lexicon (John Coleman)

Previous works in declarative phonology, e.g. Bird & Klein (1990), Bird (1990), Scobbie (1991a), Coleman (1991), Coleman (1992), Local (1992) and others have concentrated on declarative accounts of phonological structure and phonotactic constraints, i.e. structure-building accounts without extrinsic ordering or structure-changing. The morphophonological phenomena central to SPE and work in that tradition have not yet been extensively attended to by proponents of declarative phonology.

In this presentation I shall examine from a declarative perspective the segmental morphophonology of modern English proposed by Chomsky & Halle (1968), Rubach (1984), Halle & Mohanan (1985) and other work in the research area now termed "Lexical Phonology", which employs extrinsic ordering of rules, cyclical rule application and feature-changing and structure-changing rules. At first appearance, therefore, the phenomena discussed at length in Halle & Mohanan (1985) present an apparent challenge to the declarative phonology programme.

Nevertheless, I shall argue that the framework of Lexical Phonology can be recast into a declarative formalism which employs an enriched conception of lexical constituent structure to avoid extrinsic ordering and cyclic rule application (cf. Cole & Coleman (1992)). A close examination of each of the rules proposed by Halle and Mohanan shows that they can be recast as declarative constraints which are neither feature-changing nor structure-changing. For a fuller written presentation of my analysis, see Coleman (ta).

5 Declarative Phonology, Generative Phonology, and Laboratory Phonology (Janet Pierrehumbert)

In many ways, declarative phonology is in the best tradition of Chomsky & Halle (1968). It uses a mathematically coherent formalism, and has the aim of building grammars which describe all and only the possible forms of a language. These grammars can be empirically evaluated. They can support the transfer of linguistic results to speech and language technology. In these respects, declarative phonology surpasses most current work in generative phonology.

Declarative phonology posits incompletely specified lexical representations, as does Lexical Phonology and other work on underspecification theory within generative phonology. However, the force of these representations is quite different, because of the different conception of how rules apply. In current work in generative phonology, rules apply to forms which they are "contained in" (see p. 391, SPE) whereas in declarative phonology a symmetric notion of nondistinctness governs the interaction of rules with forms (as described in p. 336-37, SPE). Their force also differs because declarative phonology relies on positive generalizations and current generative theory makes extensive (and sometimes psychologically implausible) use of negative generalizations. Therefore, it is not clear how to reconstruct within declarative phonology one of the major results of Lexical Phonology, the Strict Cycle (see Kiparsky, 1985). Specifically, "feature-changing" rules are described in declarative phonology using disjunction in the morphological component and the similarity in content between these rules and the feature-filling rules is not brought out. A weakness of generative theory, in contrast, is the similarity between lexical forms and phonological rules; the concept of Structure Preservation, though central, has not yet received an adequate definition.

In general, declarative phonology should be more ambitious in seeking new empirical and typological results. To date, it has been more successful in reanalyzing generalizations proposed by generative phonologists than in putting forward new generalizations.

Phonologists who work in the laboratory do not fall into any particular theoretical school. However, many laboratory phonologists are likely to find declarative phonology congenial because of its empirical orientation, and the capability it provides for building and testing models. I also agree strongly with its claim that phonetics provides the semantic interpretation of phonology; see Pierrehumbert (1990). This claim ultimately goes beyond the grammatical character of the present theory, because the availability of objects in the phonetic stream cannot be taken for granted. The relationship of phonology to phonetics exhibits many of the problematic characteristics of reference in general, and mainstays of model theory, such as events, are not trivially supplied by descriptions of speech as a physical phenomenon.

References

Bach, E. (1983). On the Relationship between Word-Grammar and Phrase-Grammar. *Natural Language and Linguistic Theory*, *1*(1), 65–89.

Bird, S. (1990). *Constraint-Based Phonology*. PhD thesis, University of Edinburgh. (To be published by Kluwer Academic Publishers, *Studies in Language, Logic and Information*).

Bird, S. (1992). Finite-state phonology in HPSG. In *Proceedings of Coling-92*, (pp. 74–80).

Bird, S. & Ellison, T. M. (1992). One level phonology: autosegmental representations and rules as finite-state automata. RP 51, University of Edinburgh, Centre for Cognitive Science.

Bird, S. & Klein, E. (1990). Phonological events. *Journal of Linguistics*, *26*, 33–56.

Chomsky, N. & Halle, M. (1968). *The Sound Pattern of English*. New York: Harper and Row.

Cole, J. S. & Coleman, J. S. (1992). Cyclic Phonology with Context-Free Grammars. Technical Report UIUC-BI-CS-92-06, University of Illinois. (Also to appear under the title “No Need for Cyclicity in Generative Phonology” in C. Canakis, G. Chan and J. Denton, eds. *CLS 28-II: Papers from the Parasession on The Cycle in Linguistic Theory.* Chicago, IL: Chicago Linguistic Society.).

Coleman, J. S. (1991). *Phonological Representations — their names, forms and powers*. PhD thesis, University of York.

Coleman, J. S. (1992). The phonetic interpretation of headed phonological structures containing overlapping constituents. *Phonology*, *9*, 1–44.

Coleman, J. S. (*t.a.*). Declarative lexical phonology. In F. Katamba & J. Durand (Eds.), *Frontiers of Phonology: Primitives, Architectures and Derivations*. London: Longman.

Dell, F. & El-Medlaoui, M. (1985). Syllabic consonants and syllabification in Imdlawn Tashlhiyt Berber. *Journal of African Languages and Linguistics*, *7*, 105–130.

Goldsmith, J. (*t.a.*). Harmonic Phonology. In J. Goldsmith (Ed.), *The Last Phonological Rule: Reflections on Constraints and Derivations in Phonology*. University of Chicago Press.

Halle, M. & Mohanan, K. P. (1985). Segmental phonology of Modern English. *Linguistic Inquiry*, *16*, 57–116.

Hockett, C. F. (1954). Two models of grammatical description. *Word*, *10*, 210–231. (Also appeared in M. Joos (ed.) *Readings in Linguistics I*, University of Chicago Press).

Hooper, J. (1976). *An Introduction to Natural Generative Phonology*. Academic Press.

Hudson, G. (1980). Automatic alternations in non-transformational phonology. *Language*, *56*, 94–125.

Kisseberth, C. W. (1970). On the functional unity of phonological rules. *Linguistic Inquiry*, *1*, 291–306.

Lieber, R. (1987). *An Integrated Theory of Autosegmental Processes.* SUNY Series in Linguistics. State University of New York Press.

Local, J. K. (1992). Modelling assimilation in non-segmental rule-free synthesis. In G. Docherty & D. R. Ladd (Eds.), *Papers in Laboratory Phonology II: Gesture, Segment, Prosody* (pp. 190–223). Cambridge University Press.

McCarthy, J. (1984). Theoretical consequences of Montañes vowel harmony. *Linguistic Inquiry*, *15*, 291–318.

McCarthy, J. (1991). Synchronic rule inversion. In *Berkeley Linguistics Society 17*.

Paradis, C. (1988). On constraints and repair strategies. *The Linguistic Review*, *6*, 71–97.

Pierrehumbert, J. (1990). Phonological and phonetic representation. *Journal of Phonetics*, *18*, 375–394.

Pollard, C. & Sag, I. (1987). *Information-Based Syntax and Semantics*, volume 13 of *CSLI lecture notes*. CSLI.

Poser, W. (1982). Phonological representation and action-at-a-distance. In H. van der Hulst & N. Smith (Eds.), *The Structure of Phonological Representations, Part II*. Dordrecht: Foris.

Prince, A. & Smolensky, P. (1992). Optimality: constraint interaction in generative grammar. In *West Coast Conference on Formal Linguistics*. UCLA.

Rice, K. (1989). On eliminating resyllabification into onsets. *Proceedings of the West Coast Conference on Formal Linguistics*, *8*, 331–346.

Rubach, J. (1984). Segmental rules of English and cyclic phonology. *Language*, *60*, 21–54.

Scobbie, J. M. (1991a). *Attribute Value Phonology*. PhD thesis, University of Edinburgh.

Scobbie, J. M. (1991b). Towards declarative phonology. In S. Bird (Ed.), *Declarative Perspectives on Phonology* (pp. 1–26). University of Edinburgh.

Scobbie, J. M. (1992). Licensing and inalterability in Tiberian Hebrew. In Canakis, C., Chan, G., & Denton, J. (Eds.), *Chicago Linguistics Society 28-I: General Session*.

Shibatani, M. (1973). The role of surface phonetic constraints in generative phonology. *Language*, *49*, 87–106.

Singh, R. (1987). Well-formedness conditions and phonological theory. In W. U. Dressler (Ed.), *Phonologica 1984* (pp. 273–285). Cambridge University Press.

Smolensky, P. (1986). Information processing in dynamical systems: foundations of Harmony Theory. In D. E. Rumelhart & J. L. McClelland (Eds.), *Parallel Distributed Processing: Explorations in the Microstructure of Cognition*. Cambridge: MIT Press.

Wheeler, D. (1981). *Aspects of a Categorial Theory of Phonology*. PhD thesis, U.Mass, Amherst.