1:

FORMAL THEORY COMPARISON

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 comparsion 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.

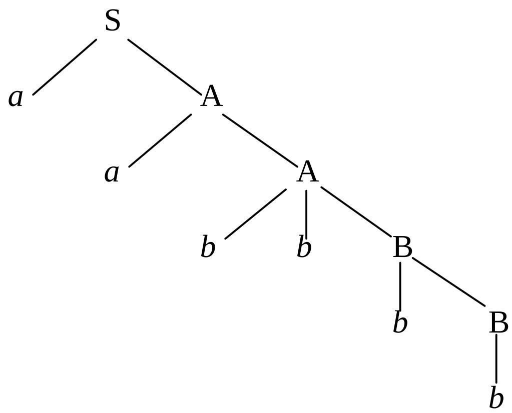
1.1.1 Automata and Rewriting Systems

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):

(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,*

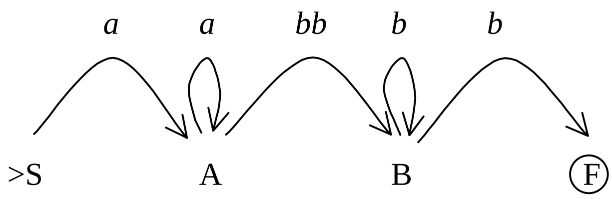
$R = \{S\rightarrow a\mathrm{A},\ A\rightarrow a\mathrm{A},\ A\rightarrow bb\mathrm{B},\ B\rightarrow b\mathrm{B},\ B\rightarrow b\}$, *a set of right-linear rules*

The rules of a right-linear grammar consist of a non-terminal symbol to be rewritten either as a terminal string (e.g. B→*b*) or as a terminal string followed by a non-terminal symbol (e.g. A→*bb*B). The derivation of the terminal string *aabbbb* of tree (1) by applying each rule in turn is shown in (3):

(3) $\mathrm{S} \Rightarrow a\mathrm{A} \Rightarrow aa\mathrm{A} \Rightarrow aabb\mathrm{B} \Rightarrow aabbb\mathrm{B} \Rightarrow aabbbb$

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:

(4)



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 (*a*s and *b*s) with the state reached (S,A,B or F) marking the position at which any further symbols are to be written[1], we have:

(5) $_{\mathrm{S}} \Rightarrow a_{\mathrm{A}} \Rightarrow aa_{\mathrm{A}} \Rightarrow aabb_{\mathrm{B}} \Rightarrow aabbb_{\mathrm{B}} \Rightarrow aabbbb_{\mathrm{F}}$

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

[1]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:

(6)	rewrite rule		transition
	$P \rightarrow xQ$	~	(P,x,Q)
	$P \rightarrow x$	~	(P,x,F)

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).[2] 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 ̙), 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

[2] 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).

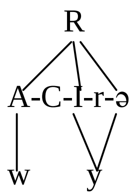
prosodic units *y* and *w* a notational treatment as predicates whose arguments are the phonematic units, enclosed in brackets. In turn, the prosodic unit R notationally takes as its argument all the other entities in the representation, enclosed in square brackets.

(7) o̘ si̘ri̘ ’he cooked’

(8) R[(A)w(CIrə)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:

(9)



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)[3]. It is true that there are differences in why prosodies or autosegments are posited, how prosodies and autosegments are to be interpreted

[3]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 alloted 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 Fogny "in order to avoid irrelevant association lines" that is reminiscent of a prosodic approach:

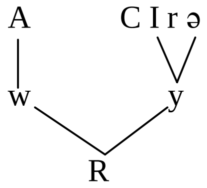
```
(10)        C V L C V
            | |  \/  |
            s a  t   e      [salte] 'be dirty'
```

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]

b.



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

a. Primitive entities are mapped under identity.

e.g. A→A, r→r, w→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

(...(...)Y...)X → a(X,Y)

This translates prosody relationships into associations.

Nested arguments are not mapped to associations on this formulation

e.g. R[..(A)...]→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 represention, 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 (Koskenniemi 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.	ll̥→lh	pal l̥a	[palha]	'dries on'
	llˀ→lʔ	yalyal lˀi	[yalyalʔa]	'clear'
b.	nl→ll	hon liːna	[holliːna]	'flies along the back'
c.	nl̥→lh	hon l̥y	[holhi]	'flies into'
	nlˀ→lʔ	hon lˀaːlˀa	[holʔaːlˀa]	'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

[+sonorant] [+sonorant]
[coronal] [+lateral]

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

[+sonorant] [+sonorant]
[+lateral] [+spread glottis]

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) nl̥
↓ (14i) leftward spread of [+lateral]: /n/ becomes /l/ preceding /l/
ll̥
↓ (14ii) right-side delinking of [+lateral]: /l̥/ becomes /h/ following /l/
lh

Although the second rule would not apply directly to the underlying representation /nl̥/, 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:[4]

(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 assocations in the output have a correspondent in the input.*

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

[4] 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)

/nl̥/	OCP {sonorant}	MAX ([+lateral])	MAX ([+nasal])	DEP (A)	MAX (A)
nl̥	*!				
ll̥	*!		*	*	
☞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 /nl̥/, 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.[5] 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 /nl̥/ 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. $1 \mapsto 4, 2 \mapsto 6, 3 \mapsto 8, 4 \mapsto 10, 5 \mapsto 12, \ldots$

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

[5] 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_A is ordered before R_B' 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 *NC̥: “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 NC̥ 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 *NC̥ interacting in different ways within a single hierarchy of constraints:

(20) (Kager 1999:86)

	ROOTLINEARITY	*NC̥	IDENT(Voice)	LINEARITY
/e:N_1-$p_2$ati/				
☞e:$m_{1,2}$ati				*
e:$m_1b_2$ati			*!	
e:$m_1p_2$ati		*!		
/sitam_1p_2a/				
sita$m_{1,2}$a	*!			*
☞sitam_1b_2a			*	
sitam_1p_2a		*!		

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. kəneɪdiənzlɪvɪnhaʊzəz

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 kəneɪdiən] 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	kæ...
2	kæ...
	...
k	kə...
	...
n	kə...

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	kæ...
output	kə...

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.[6] This is different from

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[6] 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.[7]

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,[8] and a more obvious scenario would be that the phonetic predicates are

[7] 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).

[8] 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[9]. 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

[9] 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.