The Handbook of Phonological Theory

Second Edition

Edited by

John Goldsmith, Jason Riggle, and Alan C. L. Yu



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The Handbook of Phonological Theory

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Carole Paradis, Université Laval Joe Pater, University of Massachusetts – Amherst Sharon Rose, University of California – San Diego Elisabeth Selkirk, University of Massachusetts – Amherst Harry van der Hulst, University of Connecticut Bert Vaux, University of Cambridge Jennifer J. Venditti Rachel Walker, University of Southern California Alan C. L. Yu, University of Chicago This new volume on phonological theory is in some respects a continuation of the *Handbook of Phonological Theory* published by Blackwell in 1995. The present book was several years in the making, and reflects both the changes that the field has gone through in the years since the first handbook was written, and a shift in the precise character of the questions we hope to see answered in a book such as this. As you will see in the chapters that follow, we have asked each author to take a step back from the research that has been published over the last decade in each subfield in phonology, and to ask what the broader questions are that have been the focus of investigators over a longer period of time. Having identified the long-standing questions, the authors were then asked to pass judgment – as best they could – on the degree to which the field had succeeded in providing answers to these questions.

In this way, our handbook takes on a perspective that is different from many others in linguistics. We have asked our authors to set as their primary goal to provide some grounds for determining the degree to which phonology – as a whole, and as a set of subdisciplines – displays a cumulative character, which is to say, succeeds in asking questions that are both interesting and useful in some respects, and then – just as importantly! – answering them. In particular, we asked our authors to avoid as much as possible adopting the stance of the scholar who predicts where the field will, or should, go in the next five to ten years, and what the important open questions are. While there certainly is a place for such gazing into a well-focused crystal ball, we felt that the present handbook was not that place.

Comparing the present handbook to the one that was produced in 1995, we seem to find, too, that the field has expanded: it now includes a good deal more content and emphasis on phonetics, on variation, and on computational approaches. In reality, the growth is more a matter of perspective than anything else: studies on phonetics, variation, and computation that were of interest to phonologists have existed for a long time, but the perception is now much stronger that this work is not outside the field of phonology (though of interest to some phonologists), as it is a real and integral part of the field itself. The broader range of the questions covered by the authors in this volume is testament to that change.

If we were to point to the greatest single difference between the work in the two volumes, it would have to be the considerable replacement of the analytic tools of phonological derivations within a generative framework with those optimality theories, utilizing ranked constraints from a universal inventory of violable phonological constraints. The first chapter in this volume, by David Odden, provides an illuminating overview of the nature of the questions which have been explored, with the goal of understanding the essential difference between these two approaches.

In Chapter 2, Eric Baković revisits the topic of opacity and examines its role in distinguishing ordered versus parallel phonological derivations. He demonstrates that the range of opaque relations between underlying and surface forms does not partition neatly into "counterfeeding" and "counterbleeding" classes and moreover that there are cases which fit Kiparsky's seminal definition of opacity that cannot be generated by ordered derivations.

Changes in analytic tools are often accompanied by shifts in perspectives. Age-old problems are given a fresh look while new puzzles come about, as novel theoretical tools are tested. In this respect, the emphasis on constraint interaction and monostratalism has certainly left an undeletable mark on how one thinks about the relationship between the morphological and phonological components of grammar. In Chapter 3, Sharon Inkelas surveys the pros and cons of a monostratal interpretation of the morphology-phonology interface, and details the many ways in which morphological processes can be sensitive to phonological information and vice versa, highlighting properties that any theory of the phonologymorphology interface must take into account.

In Chapter 4, Stuart Davis offers an overview of the development of moraic phonology and provides a survey of a wide range of linguistic phenomena where the mora plays an important role, including thorny issues such as the existence of moraic onsets and the replacement of moraic quantity with phonetically-defined weight sensitivity in language.

Matthew Gordon provides a broad overview of stress systems, including quantity insensitive systems and quantity sensitive systems, in Chapter 5. Gordon provides an account of what constitutes "weight" in various quantity-sensitive systems and discusses the relationship between word-level and phrase-level stress. The chapter also presents an in-depth comparison of foot-based and grid-based representations of stress and discusses their ramifications for models of stress.

John Goldsmith presents in Chapter 6 a synoptic overview of the ways of understanding the syllable that have played a role in phonological thinking over the last hundred years, emphasizing the ways – often complementary, and not always consistent – in which the different conceptions of the syllable have emerged and developed in discussions in the literature. The two most appealing approaches have based on waves of sonority, on the one hand, and constituent structure as developed by mid-century syntacticians, on the other. A few phonological theories have tried to jettison the syllable, but rarely with any lasting success, and a successful synthesis of the best of what has been learned still awaits us.

Larry M. Hyman has studied tone languages – mostly, but not exclusively, African tone languages – in great depth since the 1960s, and in Chapter 7, he offers the reader a rich account of many of the properties of tone languages that have emerged in studies over the past several decades. He asks what we have learned about how tone is different from other aspects of spoken language, and how it can nonetheless shed a great deal of light on the way in which phonological information is organized in natural language.

Sharon Rose and Rachel Walker provide a thorough overview of harmony systems that includes vowel harmony, consonant harmony, and vowel-consonant harmony in Chapter 8. They provide an account of the triggers and targets of harmony in the case of continuous sequences and when harmony acts at a distance. For the latter, they provide an analysis of segments that block harmony when they intervene between trigger and target and those that are transparent to harmony. They identify a broad dichotomy between consonant harmony on one hand and vowel harmony – including vowel-consonant harmony – on the other that is framed in terms of blocking and transparent segments and the functional grounding that provides insight into why consonant harmony does not, in general, admit transparency, while harmony with vowels does. Finally, they discuss a range of fundamental issues, including the domain of harmony, directionality, and locality.

The notion of contrast reduction has been central to many major developments in phonological theories. Yu's chapter, which is an expanded version of an article titled "Mergers and Neutralization," that appeared in the *Companion to Phonology* (Wiley-Blackwell 2011), provides an overview of the range of contrast reduction phenomena in the world's languages and past theories that try to explain the typological tendencies. Yu places a particular focus on the problems raised by covert contrasts (i.e. incomplete neutralization and near mergers). He questions the reliability of the traditional methods of phonological investigation (see also Ladd's chapter) and argues for the need to evaluate the presence and absence of a phonological contrast at a more nuanced level.

While it is undeniable that languages are products of history, the issue of how phonological explanation should take into account historical factors remains a contentious one. Hansson's chapter, which originally appeared in the journal *Language and Linguistics Compass*, reviews an wide array of theoretical stances that phonologists have taken over the years, ranging from strictly modular approaches to the more integrationalist. Hansson shows that this controversy largely stems from questions about the nature of sound change and what models of sound change reveal about the nature of phonological knowledge.

D. Robert Ladd's chapter on the role of phonetics in phonology is a good example of how the thematic questions at the center of phonological discussions have evolved over the last 15 years. The time-depth of his discussion, involving scholars working over almost all of the twentieth century, is considerably deeper than that found in any of the chapters in the 1995 volume, and Ladd explicitly

draws together the views that Trubetzkoy developed in the 1930s with those at the heart of classical generative phonology and those that scholars today are developing, often under the influence of far richer computational resources than was imaginable even 25 years ago. The easy assumptions that phonetic reality can be modeled with a well-designed symbolic representation, such as that produced by the International Phonetic Association, have been widely challenged, and Ladd asks what alternative empirical accounts are available to us now for characterizing the nature of phonetic reality.

As noted earlier, a major change since the last edition of this handbook has been the rise in prominence of phonetic, variationist, and computational approaches in phonological investigation. A clear reflection of this is in the greater willingness on the part of many phonologists to engage data sources that have not played a large role in early theoretical developments. In their contribution, Ernestus and Baayen review findings of recent corpus-based studies of sound patterns and highlight important lessons to be learned from such studies. The appearance of what might in former times be thought of as "messy data" in the phonological discourse has invited renewed discussion on the abstractness of phonological knowledge, which the authors integrate by comparing the merits of abstractionbased vs. exemplar-based models of phonology.

In Chapter 13, Andries Coetzee and Joe Pater discuss several theoretical approaches to variation in phonology. It is fair to say that the emergence of wide-spread interest in variation among theoretical phonologists is one of the more significant changes in the field at large since the publication of the 1995 *Handbook of Phonology* (which did not contain a chapter on variation). Coetzee and Pater review a range of proposals in which variation is taken to illuminate the core phonological grammar rather than obscure it. Instead of regarding variation as a performance-related epiphenomenon that must be factored out in order to characterize the phonological grammar, they focus on understanding the locus (or loci) of variation in the grammar and the empirical consequences of various assumptions in this regard.

Lisa Selkirk has been doing influential work on the interface between phonology and other components of the grammar for over three decades. In Chapter 14, she discusses the interface between phonology and syntax in terms of the relationship between syntactic constituents and prosodic constituents. She presents a thorough account of the way that prosodic constituent domains for phonological and phonetic phenomena at the sentence level are related to syntactic constituency.

A domain where interests in phonetic and phonological investigations have converged in recent years is the area of intonational research. In their chapter on intonation, which is a slightly revised version of their contribution in the *Handbook of Phonetic Sciences* (edited by Hardcastle, Laver, and Gibbon, 2009), Beckman and Venditti review the development and advances of experimental intonational research and highlight their contributions to the understanding of intonational phonology and prosodic typology.

In Chapter 16, Harry van der Hulst presents an overview of work on governmentand dependency-based phonology, which explores the consequences for phonological theory of developing phonological representations that incorporate in an essential way formal asymmetrical relationships between abstract elements. "Asymmetrical" here refers to the important differences between what are called the head and the dependent, connected by a relation of dependency. Van der Hulst reviews recent work in this area, and notes respects in which government phonology has brought out parallels involving relations between elements in syntax and in phonology.

Katherine Demuth discusses in Chapter 17 the ways in which contemporary phonological theory has been reflected in the research concerns of a large part of the language acquisition community. Among the themes whose importance has grown over the last two decades are the relevance of surface-oriented phonological patterns, of prosodic patterns at both the syllable and foot level, of markedness and underspecification, and frequency. At the same time, conclusions can be drawn that are more robust in light of the wider range of languages that have been studied by acquisition researchers.

In Chapter 18, John Coleman guides the reader through the developments over the last 50 years which have influenced phonological modeling, bringing out the often only tacit connections between computational conceptions and phonological analyses, such as those employing finite-state methods, purely declarative formalisms, or techniques based on neural networks.

As phonologists rely more and more heavily on experimental methodologies, the question of the psychological status of phonological constructs becomes ever more important in the analyst's mind. Goldrick (Chapter 19) explores the notion of psychological realism in phonological inquiries, highlighting the need to differentiate at least three levels of analysis: functional, algorithmic, and neural. Using well-formedness judgments as a case study, he emphasizes the need to articulate in greater specificity the functional architecture of language processing in the context of interpreting experimental results.

Adam Albright and Bruce Hayes present an account of phonological learning in Chapter 20. They focus on formal systems designed to model the path by which children acquire the phonological grammar of their first language and evaluate the adequacy of the systems in terms of their ability to elucidate what is known about linguistic competence in three specific areas. The areas that they give special attention to are phonotactic knowledge, phonological alternations, and patterns of variation. They argue that any system capable of mimicking human performance in these areas – including the mistakes – will have reverse-engineered key aspects of the phonology of natural language in a way that enriches our understanding of both theoretical phonology and the broad character of observed phonological phenomena.

Diane Brentari's chapter on the phonological structure of sign languages extends her chapter on the subject in the 1995 edition of the handbook. In the current chapter, she reviews our better understanding of three important aspects of sign languages: their phonological structure, their iconicity (that is, the principles and patterns relating phonological structure to real or understood world structure), and the respects in which the phonologies of sign language are influenced by the physical modality used, notably the structure of the signing hands and body, and vision, which is the perceptual system used for perception.

The last two chapters focus on linguistic evidence that has often been taken to be extralinguistic. Both sets of authors instead argue for the centrality of such evidence in testing and advancing phonological theories. In his chapter on language games (Chapter 22), Vaux provides an overview of the empirical and theoretical advances language games have contributed to phonological research. He argues that research on language games not only reveals subtleties of phonological representation, they also shed light on the cognitive limits of linguistic operations and language acquisition, as well as architectural issues such as opacity. In their chapter on loanword adaptation, the last chapter of this book, two veteran loanword phonologists offer a summary of major findings in loanword adaptation research, and reflect on major lessons learned from this line of inquiry. Echoing Ernestus and Baayen's call for more corpus studies in Chapter 12, Paradis and LaCharité illustrate in Chapter 23 the importance of corpus construction and the need to pay attention to statistical generalizations with their own Project CoPho loanword database.

We offer these chapters to both the reader who is relatively new to the field and to the expert knowing full well that no-one can keep fully up to date on all the fields that now comprise phonology. We thank our authors for their efforts, as well as for their patience and forbearance during the book's preparation, and we hope that our readers will profit from the chapters as much as we, the editors, have.

We would like to dedicate this book to the memory of G. N. Clements, who was planning to contribute a chapter to this handbook, and who left us too soon to able to do so. Like many others, we admired Nick's work and were influenced greatly by that work, and we will miss him.

1 Rules v. Constraints

DAVID ODDEN

1 Background

The goal of a theory of phonology is to elucidate the nature of "phonology" at a conceptual and predictive level. The title of this chapter refers to a comparative evaluation of rules and constraints as successful theories of phonology, which implies having a standard of evaluation, and adequate clarity as to what "rules" and "constraints" refer to. Neither prerequisite is trivial to satisfy.

1.1 The Scope of Inquiry

Certain assumptions about the nature of phonology must be considered, even lacking agreement on which assumptions to make. First and foremost, deciding whether phonology is based on rules or constraints, or a mix of the two, requires having objectively expressible statements of phonologies within different frameworks whose consequences can be compared. Therefore the theories must have a definite form, that is, they must be formalized. The entities which make up a phonological grammar should be expressions, which are finite sequences of elements taken from a specified set, and combined by rules of construction that define well-formed statements of rule or constraint. The value of formalism is its power to make objectively-interpretable statements about the phonology which can be checked against fact. To evaluate rules versus constraints as models, we should then consult the formalisms of the theories, to see whether one theory better passes the test of empirical and aesthetic adequacy.¹ Problems in this area are not trivial; certain theories of constraints or rules are severely under-formalized so that it is hard to know what predictions the theory makes; and a number of

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theories are under-applied in the sense that it is impossible to determine from examples how particular phenomena would be analyzed.

Assuming that we are comparing formal theories, we must resolve questions about the scope of phonology, including how much of "phonetics" or "morphology" is phonology, and whether all facts bearing on phonology are the responsibility of the theory. Generative phonology traditionally encompasses a broad range of processes which might be considered phonetic (allophonic) or morphological (rules with lexical or morphological conditions), but the edges of phonology may also be contracted for theoretical purposes, viz. restrictiveness. Thus Webb (1974: 127) excludes metathesis from phonology, stating that "synchronic metathesis is not a phonological process. In the residual cases of metathesis, the rule is always morphologically restricted," enabling the "Weak Metathesis Condition," a restriction against reordering in phonology. If phonology is deemed to be concerned only with biuniquely recoverable surface-true relations between sounds (e.g. allophonic vowel nasalization in English), and abstract phonological alternations are to be described by the formal methods of morphology, a theory designed to account for just surface phonotactics cannot be meaningfully compared to one designed to account for both phonotactics and abstract morphophonemics.² A surface-phonotactic view of phonology thus must ignore a substantial portion of research into phonological grammars, on Bedouin Arabic (Al Mozainy 1981), Finnish (McCawley 1963; Harms 1964; Karttunen 1970; Keyser and Kiparsky 1984; Kiparsky 2003a), Chukchi (Krauss 1981), Kimatuumbi (Odden 1995), Klamath (Kisseberth 1973; White 1973), and Ojibwa (Piggott 1980), and numerous other languages.

There are also questions as to the level of explanation demanded of a theory – do we demand formal explanation, or formal and functional explanation? Much of the course of phonological theorizing has involved the increasing absorption of substantive factors into the theory, in an attempt to narrow the gap between prediction and observation. Comparative evaluation of theories implies determining which theory is better at making definite the notion "possible rule" or "possible constraint." The notion "possible" is used in two ways. One sense is theoretical well-formedness, that is, a rule constructible by free combination of elements, according to a theory of the form of rules. In that sense, " $A \rightarrow B/C_D$ " would be a possible rule, but " \rightarrow B_/ACD" would not. McCawley (1973: 53) points to a different sense, the metaphysically possible, claiming "One who takes 'excessive power' arguments seriously has as his goal characterizing 'phonological rule' so as to include all and only the phonological rules that the phenomena of a natural language could demand...." This notion of "possible rule" seems to mean what does exist, so is attested, or that which we have solid scientific or philosophical reason to conclude *must exist* now or in the past or future, just waiting to be discovered. The latter kind of "possible" depends on metatheoretical expectations, so McCawley intuits that assimilation of nasal to labials alone is not a possible rule (the present author does believe that such a rule is possible, if unlikely).

Whether such a rule is possible is not central to this discussion: what is essential, is distinguishing the undiscovered from that which is impossible by the nature

of language. Expansion of the substantive content of phonological theory narrows the predictive gap, though, complicates the theory and renders it redundant with respect to the extragrammatical physical explanations for the gap. If phonology is only a system of symbolic computations where the syntax of computations defines a broad class of possible rules, and separate aspects of languages referring to substance (perception, acoustics, articulation, language learning, and the transduction between grammar and linguistic behavior) explain why some formally allowed rules have negligible probability of attestation (as argued by Hale and Reiss 2008; Morén 2007), then failure to capture a generalization about substance within the theory of computation is not an argument against the theory of computation. But there is no universal agreement that the object of investigation *is* the computational apparatus rather than the full and undifferentiated panoply of factors influencing linguistic sound.

A second metatheoretical question affecting a comparison is whether phonology describes abstract string collections, or the mental faculty which generates them. If phonology only models strings, then considerations such as the results of psycholinguistic tests or problems regarding infinities in the model – infinite sets of candidate or sub-rules – are irrelevant to theory selection.³ An example of how different conclusions are reached depending on whether one considers just the strings, versus the strings plus the mechanisms, is Mohanan (2000: 145–146) versus Calabrese (2005: 34). Mohanan contends that a rule [+nasal] \rightarrow [+voice] is "logically equivalent" to a negative constraint *[+nasal,-voice], while Calabrese contends that rules and constraints are totally different means of implementing a linguistic action and are ontologically different. Mohanan is correct that the rule and the constraint describe the same string classes – are weakly equivalent; Calabrese is right that the imputed mental mechanisms of rules versus constraints are different – are not strongly equivalent.⁴

Even if we presume that phonology should be concerned with a mental faculty as well as the sets of strings, we must also determine whether phonology is concerned with all sound-related behavior, or just that behavior which generates the strings. A mentalist view of phonological grammars would care whether insertion of [i] after a word-final obstruent is regulated by a rule or a constraint, and whether this takes place in a single step or many steps; but a mentalist view of phonological grammars does not automatically care about the behavior of speakers of such a language under certain types of psycholinguistic testing, since a mentalist view of grammar does not automatically hold that all aspects of the mind pertaining to language sound are contained in the phonological component of a grammar.

To properly contrast "rules" versus "constraints" in phonology, we must also determine what these terms refer to, because we want our conclusions about differences between rules and constraints to reflect the concepts themselves, and not quirks of particular theories of rules or constraints. Many definitions of "rule" are offered in the Oxford English Dictionary, but the ones that seem closest to its linguistic use are:

A fact (or the statement of one) which holds generally good; that which is normally the case.

- A principle regulating the procedure or method necessary to be observed in the pursuit or study of some art or science.
- (Grammar). A principle regulating or determining the form or position of words in a sentence. In modern linguistics, usually applied to any one of a system of rules that can be formulated in such a way that together they describe all the features of a language.

The closest applicable definition of constraint is

The exercise of force to determine or confine action; coercion, compulsion.

In addition, the terms "principle," "condition," and "convention" are often used in linguistics to describe what often seems to be the same thing as a constraint, perhaps with the implication of greater generality or a stronger commitment to universality.

In other words, the terms "rule" and "constraint" have developed into terms of art in linguistics, requiring special definition, and the ordinary meanings of the words only have an approximate correspondence to their linguistic use. The original formal notion of a "rule" derives from the computational notion of Post production systems, developed in the 1930s by Emil Post (Post 1943). In generative grammatical theory, the essential characteristic of a *rule* is that it maps classes of strings onto other classes of strings in a specific way: the rule encodes the particular change. Classically, rules in generative grammar also have the Markov property, that the device or rule refers only to its current state (the input string) and not some future or past state or string – such a device is "Markovian."⁵ Thus a rule which states "AXB \rightarrow AZB" means "if you find a string analyzable as AXB (at the current stage of the derivation), it maps to AZB (at the successor stage)." A non-Markovian rule could refer to facts of a prior stage in a derivation.

Constraints are less well-defined largely due to the fact that their primary characteristic is "not being a rule."⁶ A constraint is essentially a "limit," so the exact nature of a constraint depends on whether one is constraining a rule, a derivation, or a representation. Contemporary usage sees constraints as evaluating structures, but originally, constraints were limits on rules, typically defined in terms of a string property. The property of "overarching, non-local influence," that is, relevance to something more than one rule, is another behavioral characteristic of constraints. Constraints can be either Markovian (morpheme-structure or surface well-formedness constraints, which state generalizations at one level) or non-Markovian (transderivational constraints on input-output relations, OT Correspondence Constraints, the Elsewhere Condition), but are typically not seen as *holding of* just one rule or step in a derivational mapping, assuming derivations.⁷ The general concept "constraint" does not say whether the mechanics of grammar allow constraints to be violated, and says nothing about how constraints are enforced or how potential or actual violations are handled. Constraint-based theories differ considerably in this respect, some theories (Declarative Phonology) disallowing violations of constraints, others (famously, OT) allowing them.

To anticipate the results of this investigation, there is no substantial difference between rules and constraints per se in their power to deal with phonological systems. The important differences reside in properties of particular theories of rules and constraints. Different theories of rules and constraints combine simple theoretical properties in many ways. For example, "surface-trueness" is a property sometimes associated with constraints and not rules, but some rule theories require the rules of language to be surface true (Natural Generative Phonology; Equational Grammar, Sanders 1972b), and OT is founded on the idea that constraints can be violated. The most important properties of the formal statements used in rule or constraint systems which we will be watching for are:

Globality: the statement applies "generally" in a language, not just at one point. (*Language*) *Universality*: the statement pre-exists in UG: is not dependent on exposure to a particular language.

Inviolability: the statement must be true of particular levels of representation. *Negativity*: the statement may give conditions that must not hold.

Ordering: the statement interacts with other statements according to language-specific priority.

Multiple Representations: more than one representational string is involved in computing the output form.

1.2 The Seeds of the Rule/Constraint Distinction

While the idea of directly and literally stating all of the facts of the mapping performed by a rule within the formalization of the rule itself would seem to characterize rule-based grammar, such a theory has never existed, and generative grammar has always operated with local rules and global meta-principles of rule interpretation. Nevertheless, the development of the concept "rule" in generative grammar from the most direct and literal statement of string-to-string mapping inevitably gave rise to the separate concept "constraint," when linguists faced recurring linguistic regularities which were not easily expressed in a general-purpose symbol-manipulation algebra. In saying that rules map classes of strings onto classes of strings, we recognize that rules use abbreviatory expressions to reduce classes of objects to compact symbols, for example a symbol to represent "consonant" or "NP." Rules are not written to apply exclusively to particular concretes such as [f] or *the child*. Formal linguistic statements are necessarily written with an abbreviatory notation referring to linguistic objects, and conventions that transcend a specific rule must be established for interpreting rules.

The development of the distinction between rules and constraints began in syntax, and early concepts of phonological constraints were a direct consequence of the prior development of such ideas in syntax – the implicit goal is to develop a theory of grammar. Early generative grammar as exemplified by Chomsky (1957, 1965) depended heavily on rules which explicitly stated the operations performed. Thus the Particle Shift transformation in Chomsky (1957: 112) is stated as "X-V1-Prt-Pronoun \rightarrow X-V1-Pronoun-Prt," that is, when a particle precedes a pronoun,

the pronoun obligatorily moves to precede the particle: a separate optional rule addresses the situation where the word after the particle is a full non-pronominal NP. In this rule, X is taken by general mathematical convention to be a variable representing "any sub-string." Chomsky considers (p. 76) but does not formalize a generalization to the effect that ordinarily optional Particle Shift is obligatory *if* the post-verbal nominal is a pronoun, setting the stage for higher-order "conditions" on rule application separate from classical string-rewriting rules. Such a generalized version with an "obligatory if pronoun" condition does not follow the simple string-rewriting model, indicating that something in addition to string-rewriting statements are required.

A principle of Chomsky (1964: 931), dubbed in Ross (1967) the "A-over-A principle," gave rise to the first explicit constraints in generative grammar. This principle asserts that "if the phrase X of category A is embedded within a larger phrase ZXW which is also of category A, then no rule applying to the category A applies to X (but only to ZXW)." That is, when category A dominates an A, how is reference to "A" in a rule interpreted with respect to a string – as applying to the higher A or the lower A? According to this principle, interpretation of "A" is limited to just the higher A. A-over-A is not a rule (it does not state a string mapping), and it is global rather than local. It thus had a separate status, as a limitation on grammars, and an autonomous and universal claim about the notion "rule of grammar."

The consideration of factoring generalizations out of rules and giving them independent status – the globality property – took on a major role in linguistics with Ross (1967), who argues for the unambiguous necessity of autonomous constraints in grammar, in order to account for the facts covered by A-over-A. Ross argues that greater generality and simplicity can be achieved by removing certain considerations from explicit rule statements, and giving them the status of separate limitations or constraints on grammars. Since a rule is one derivational mapping, the only means of propagating a formal identity across rules in early generative rule theory was via a convention which defines a notation, for example, "X *means* a string of symbols of unbounded length." Ross-constraints change the conception of language because those statements cannot be reasonably construed as "defining the meaning of formal symbols," but they also are not linearly ordered string-rewrite rules.

The first constraint postulated by Ross is S-pruning (p. 26): "delete any embedded node S which does not branch . . . ," motivated by the fact that syntactic theory at that time held, counter-intuitively, that "his" and "yellow" in "his yellow cat" are sentences. Ross comments (emphasis added) "This principle should *not be thought of as a rule* which is stated as one of the ordered rules of any grammar, but *rather as a condition upon the well-formedness* of trees, which is *stated once in linguistic theory*, and applies to delete any non-branching S nodes which occur in any derivations of sentences in any language." In terms of globality and the statement of well-formedness, S-pruning has clear affinities to a constraint, but insofar as it also includes a statement of repair – the principle is not interpreted to mean "block a rule that *would* create such a structure" – S-pruning resembles

a rule. Other constraints such as the Complex NP Constraint – "No element contained in a sentence dominated by a noun phrase with a lexical head noun may be moved out of that noun phrase by a transformation" – exert a blocking influence, preventing wh-movement from generating *"Who does Phineas know a girl who is jealous of."

The constraint-based tactic, best summarized in Ross (1967: 271), is "that many conditions previously thought to be best stated as restrictions on particular rules should instead be regarded as static output conditions, with the rules in question being freed of all restrictions": recurring aspects of multiple rules can be factored out and stated separately, making the formal statements of the rules simpler. Extraposition from NP thus need not explicitly list the content of its right-edge variable, to block the sentence *"That a gun_i went off surprised no one which I had cleaned ___i." Instead, this effect is achieved via a rule-independent principle – a constraint – on the content of variables in certain kinds of rules. Constraints might be universal (the Coordinate Structure Constraint was claimed to be universal) or language specific (the Pied-piping constraint is language specific).

Constraints typically had two realizations in early generative grammar, blocking and filtering. The blocking function says that if a particular rule application would contradict some constraint, the rule could not apply. Ross's Coordinate Structure Constraint thus blocks wh-movement from applying to "Bill and who bought biscuits?" The notion of "filtering" is brought out explicitly in Chomsky (1965: 137–139), to explain why the relative clause and higher NP must contain identical nouns, to prevent an unrealizable deep structure [the man [Bill saw the woman]]. Chomsky notes (pp. 138–139) "The transformational rules act as a 'filter' that permits only certain generalized phrase-markers to qualify as deep structures." Blocking and filtering are not particularly distinct when applied to optional rules (as syntactic rules have sometimes been held to be), and blocking an optional rule is string-equivalent to freely applying the rule and then filtering out violations of the constraint. Constraints and filtering achieved greater prominence in such works as Ross (1967), Emonds (1970), Perlmutter (1971), Hankamer (1973), Lakoff (1973), for instance and, as we will see below, a number of works in phonology.

2 Rules in Phonology

The concept of a (synchronic) generative phonological rule was developed in such works as Chomsky (1951), Halle (1959b, 1962, 1964), Chomsky and Halle (1965), Kiparsky (1965), Lightner (1965), McCawley (1965), Schane (1965), Zwicky (1965), Sloat (1966), Harris (1967), culminating in the essential reference work in the theory of generative rules in that era, Chomsky and Halle (1968). In this theory, often called the SPE ("Sound Pattern of English") theory, a grammar is a linearly ordered sequence of rewrite rules mapping an underlying form (the output of the syntax) to the surface representation.

The main theoretical concerns of phonology were the sub-theories of ordering, features, and rule formalism. All three aspects must be considered in evaluating

the theory against its competitors. Representation and rule statement are closely related since rules map between representations. Ordering bears on the question since some constraint-based theories preclude ordered derivational steps, and because a rule implies at least two levels, the input and output.

2.1 Rules and Conventions

A grammar is a linearly ordered sequence of rules, and, as is characteristic of generative formalism at the time, a rule is defined (Chomsky and Halle 1968: 391) as:

 $Z X A Y W \rightarrow Z X B Y W$, where A and B may be φ or any unit; $A \neq B$; X and Y may be matrices; Z or W may be C_i^{∞} for some *i*; Z, X, Y, W may be null; and where these are the only possibilities.

Feature matrices identify sets of segments by conjoining specified features, thus the expression [+high,-voice] refers to the set of all segments which are both +*high* and –*voice*. Since the vast majority of phonological rules operate on just a single segment at a time, rules were usually stated in a format that factors out the non-changing segments, thus $B \rightarrow C / X$ _Y where X, Y could be any string of matrices, and B and C are a matrix or the null string.⁹

Given this characterization of rule, any mapping from specific string to specific string is possible (meaning, allowed by the syntax of rule construction) – a rule $mowziz \rightarrow mid|tawn$ is a possible rule, and so is the following, which refers to classes of string:

(1) X [+syllabic] [+nasal] $Y \rightarrow X$ [+syllabic,+nasal] [+nasal] Y

However, not every mapping of string *class* to string *class* is possible. Feature theory defines possible matrices, and given the nature of SPE's feature theory, the set { α , m, š, u, g} cannot be referenced to the exclusion of {a, n, i, I, u, s, b, p, t, k}, so no rule can effect the mapping:¹⁰

(2) $\{\mathfrak{X}, \mathfrak{m}, \mathfrak{S}, \mathfrak{v}, \mathfrak{g}\}_i \rightarrow \{\mathfrak{S}, \mathfrak{v}, \mathfrak{g}, \mathfrak{X}, \mathfrak{m}\}_i / \{\mathfrak{a}, \mathfrak{n}, \mathfrak{i}, \mathfrak{I}, \mathfrak{u}, \mathfrak{s}, \mathfrak{b}, \mathfrak{p}, \mathfrak{t}, \mathfrak{k}\}$

That is, even though any rule (as defined above) is possible, not every imaginable mapping of string class to string class is a possible rule in the theory. A rule in SPE is local (not global), not universal, positive (not negative); rules are linearly ordered, there can be multiple representations (a derivation), and while rules are not violated in the immediate output of the rule (modulo lexical exceptionality and optionality), they need not be true of any level.

The notion of "rule" becomes more complex because in SPE, sets of elementary rules can be combined into rule schemata via auxiliary expressions, for the purpose of grammar-evaluation and ordering. The notion of "evaluation" plays a significant role in grammatical theory – the assumption is that children learning a language are faced with multiple competing hypotheses which need to be

evaluated, the best one being the one actually acquired. The claim of the theory is that when rules resemble each other in specific ways, this resemblance is a significant linguistic generalization which needs to be captured. For example, a grammar could contain the following pair of elementary rules:

$$\begin{array}{ll} (3) & [+A] \rightarrow [-D] \ / \ _ \begin{bmatrix} +E \\ -F \end{bmatrix} \\ & \\ [+A] \rightarrow [-D] \ / \ _ [-G] \end{array}$$

The similarity between these rules can be captured via a notational device, the brace notation, whereby a single statement can express these two elementary rules:

$$(4) \quad [+A] \to [-D] / ___ \left\{ \begin{bmatrix} +E \\ -F \\ [-G] \end{bmatrix} \right\}$$

which means "Any segment which is [+A] becomes [-D], when it stands before either a [+E,-F] segment or a [-G] segment." The significance of such abbreviation is two-fold. First, the evaluation metric assigns a greater value to a sequence of rules which can be collapsed via an abbreviatory convention than a similar uncollapsible rule sequence, and second, sub-rules abbreviated with abbreviatory devices apply disjunctively,¹¹ so only one of the rules in a schema can apply to a given segment. The evaluative function of abbreviatory notations was the most important, because language acquisition was seen as the process of selecting the formally simplest grammar consistent with the data. Abbreviatory devices then say that certain sets of rules are simpler in the sense that their "cost" is a fraction of the cost of the total set of individual rules. The mappings described as {æ, m, š, u, g} \rightarrow {š, u, g, æ, m} / {a, n, i, I, u, s, b, p, t, k} ____ can only be accomplished via a highly disvalued list of unreducible changes æ \rightarrow š / a_ ; æ \rightarrow š / n_ ; m \rightarrow u / a_ ; etc.

Other devices were employed to express optional elements, so the context "___([+A])[-C]" means "when the segment precedes something that is [-C], with or without one intervening [+A] segment," and "___[+A]_0[-C]" means "before a [-C], with any number of intervening [+A] segments." Another significant device was the feature-coefficient variable, typically expressed with Greek letters $\alpha,\beta,\gamma\ldots$ which represented the two feature values {-,+}. This notation was widely used to express assimilation processes, such as the following place assimilation for nasals.

(5)
$$[+nasal] \rightarrow \begin{bmatrix} \alpha ant \\ \beta cor \end{bmatrix} / __\begin{bmatrix} -syl \\ \alpha ant \\ \beta cor \end{bmatrix}$$

This abbreviates the following four rules.

$$(6) \quad a. \quad [+nasal] \rightarrow \begin{bmatrix} +ant \\ +cor \end{bmatrix} / \dots \begin{bmatrix} -syl \\ +ant \\ +cor \end{bmatrix} \qquad c. \quad [+nasal] \rightarrow \begin{bmatrix} -ant \\ +cor \end{bmatrix} / \dots \begin{bmatrix} -syl \\ -ant \\ +cor \end{bmatrix}$$
$$b. \quad [+nasal] \rightarrow \begin{bmatrix} +ant \\ -cor \end{bmatrix} / \dots \begin{bmatrix} -syl \\ +ant \\ -cor \end{bmatrix} \qquad d. \quad [+nasal] \rightarrow \begin{bmatrix} -ant \\ -cor \end{bmatrix} / \dots \begin{bmatrix} -syl \\ -ant \\ -cor \end{bmatrix}$$

Various aspects of the theory of rule formalism and schemata are set forth in SPE, especially pp. 393–399 for rule schemata, including X_0 , X^* and other notations. See also Bach (1968) for the Neighborhood Convention notation.

The complement notation suggested in Zwicky (1970) introduces "negativity" into rule statements which otherwise state what must hold for a rule to apply, since the complement notation refers to "anything but," that is, what must not hold, for a rule to apply. An example of that kind is the *ruki* rule of Sanskrit, where /s/ becomes [s] after the class r, u, k, i, provided that the following segment is not /r/. The right-hand context could be expressed "-[+son,-nas,+cor]" or "~[+son,-nas,+cor]" with the complement notation. As Zwicky notes, the complement of a natural class – a feature conjunction – is, by DeMorgan's law for negation of a conjunction, equivalent to a disjunction of negated values $(\neg(A \land B) \equiv (\neg A \lor \neg B))$, thus the right-hand condition can be stated as $\{-\text{son},+\text{nas},$ -cor}. A simple translation between direct statement of context and complement statement is possible for a single matrix being a blocking context, but not for a segmental sequence. Suppose a rule applies after certain segments but is blocked when immediately followed by [ba]. Simply changing conjunction to disjunction and reversing signs on the right-hand context does not give the desired effect. Such a conversion applied to the expression:

$$(7) \quad -\begin{bmatrix} +\text{voice} \\ -\text{cont} \\ -\text{nas} \\ +\text{ant} \\ -\text{cor} \end{bmatrix} \begin{bmatrix} +\text{syl} \\ +\text{low} \end{bmatrix}$$

would give:

$$(8) \quad \begin{cases} -\text{voice} \\ +\text{cont} \\ +\text{nas} \\ -\text{ant} \\ +\text{cor} \end{cases} \begin{cases} -\text{syl} \\ -\text{low} \end{cases}$$

which means "anything besides [b] followed by anything besides [a]." The difference in the two expressions lies in the fact that with the complement notation, the sequence [bi], [da] on the right would not block the rule, but with the negated disjunction approach, such sequences would block. This points to an important question about blocking conditions, namely, does blocking ever require the characterization of a sequence of segments, or do blocking effects always involve the complement of a single element? A further point about blocking effects is that the negated disjunction statement presupposes the brace notation, and the validity of the brace notatation in phonology has been called into question, for example, by McCawley (1973). The connection with constraints should be clear, since a rule that applies except when a configuration is present is extensionally equivalent to one subject to an output condition, that is, a constraint against the configuration blocks the rule.

The SPE-era abbreviatory conventions were received skeptically: see McCawley (1973) for discussion. An important question raised there is whether the notations do, as claimed in SPE, represent sets of independently-existing sub-rules – the various sub-rules actually exist in the grammar and are simply evaluated as a single unit – or are the notations first-order concepts? The notations which abbreviate infinite set (X* and X₀) cannot represent the collapsing of sets of rules in a grammar at least under a "model of the mind" view of grammar since a mental grammar cannot contain an infinity, so some of the SPE notational conventions must be primitive and not abbreviatory.

McCawley proposes, regarding feature variables, that the notion of feature identity should be a first-order concept in rule theory, so that a rule assimilating the coronality value of segment 1 to that of segment 2 would encode this as "coronal(1) \rightarrow coronal(2)," meaning "the value of coronal for 1 becomes whatever it is for 2." The significance of this change to the theory is that it narrows the gap between observation and formal prediction, ruling out a large class of rules which are expressible in the SPE notation, such as:

$$(9) \quad [+syl] \rightarrow \begin{bmatrix} \alpha hi \\ \beta low \\ \gamma back \\ \delta round \end{bmatrix} / ___ \begin{bmatrix} +syl \\ \delta hi \\ \alpha low \\ \beta back \\ \gamma round \end{bmatrix}$$

where features and values are mismatched. See Reiss (2003) and Section 2.4 for further discussion.

The main objection to the abbreviatory devices proposed in SPE is that large classes of non-generalizations could be expressed. The "dash-factoring" notation (p. 338):

(10)
$$X \to Y / \begin{bmatrix} - & \\ & Z \end{bmatrix} Q$$

which means "Before Q, anything that is X becomes Y when it is also Z" was also little-used, and was seen as a spurious economization, being extensionally equivalent to the expression "anything that is both X and Y." Apart from being a capricious "use it if you want" device, this device was used to coerce collapsibility in rules that could not otherwise be formally collapsed, such as the SPE Tensing rules (Chomsky and Halle: 241).

The star-parenthesis notation was motivated in that it was used to express a fact of language, but was supplanted by the theory of rule iteration (Howard 1972; Jensen and Stong-Jensen 1973, Kenstowicz and Kisseberth 1977). Angled brackets were employed for various purposes, primarily structure-preserving side-effects (e.g. in Slavic velar palatalizations where *k* becomes [č] but /g/ becomes [ž] and not [\tilde{J}]). The brace notation was also viewed with skepticism, especially since the majority of recurring uses pertained to syllable structure and typically involved finding a way to make {C,#} be a natural class. The parenthesis, subscript-zero and variable feature notations were fairly well motivated in that phenomena which the devices were predominantly used for are not easily deniable. These notations still posed significant predictive problems. For example, factoring a string into units of two for stress purposes was not difficult (see (11a)) and appropriately so because binary stress units are well attested, but it was no harder to factor strings into groups of seven, thus the formal theory overgenerates.

(11) a.
$$V \rightarrow [+stress] / \# C_0 ((VC_0)_2^2)_0 _____$$

b. $V \rightarrow [+stress] / \# C_0 ((VC_0)_7^7)_0 _____$

Nasal place assimilation (5) is evaluated the same as the unattested rule (12).

(12)
$$[+nasal] \rightarrow \begin{bmatrix} \alpha \text{ant} \\ \beta \text{cor} \end{bmatrix} / ___\begin{bmatrix} -\text{syl} \\ \beta \text{ant} \\ \alpha \text{cor} \end{bmatrix}$$

The class of attested rules of natural languages that motivate feature-variable notation seems to be a small fraction of the set of predicted rules, which is quite problematic if the theory is held responsible for distinguishing "actual languages" from "non-languages." The advent of nonlinear phonology seemed to eliminate the motivation and need for these notations (though see below), where a different theory of representations resulted in the possibility of expressing the facts at least as well. A similar trade-off between representational richness and statement-impoverishment is to be found in certain constraint-only theories, including Candidate Chains in OT and Declarative Phonology.

2.2 Blocking and Repairing Conventions

While the SPE theory with abbreviatory notations does a remarkable job, by comparison to previous formal theories of phonology, in characterizing possible versus impossible grammars and matching that to attested languages the theory mispredicted the possibility or probability of phenomena. Some of this stems from the substance-free nature of formalism, which counter-intuitively puts palatalization before back vowels and palatalization before front vowels on an equal footing. On the assumption that this should be addressed by the formal theory, SPE introduced a major departure from strict rule theory, via a set of universal "rules" (not part of a grammar: p. 403), namely the markedness rules which encode aspects of phonetic substance. Given the device of linking, these rules automatically and globally modify the immediate output of rules. This introduces the notions of automatic repair and persistent rule, which played a major rule in the operation of non-linear phonology.

Under the markedness and linking proposal, lexical representations may have the values "u" (unmarked) or "m" (marked), which map to plus and minus by universal rules such as [*u*low] \rightarrow [-low], [*u*del.rel] \rightarrow [+del.rel]/[___ant,+cor] (pp. 419–435). These rules also apply to the output of phonological rules, so given a rule changing F, a feature G whose unmarked value depends on F may be reassigned by a markedness rule. In Slavic, the rule [-ant] \rightarrow [-back] / ___ [-cons, -back] derives /k g x/ \rightarrow [č j š]. Without markedness rules, this would only result in *[k^y g^y x^y]. A direct statement of the actual change requires more complex formulation with angled brackets (which encode discontinuous dependency not expressible via parentheses):

(13)
$$\begin{bmatrix} -ant \\ <-cont > \end{bmatrix} \rightarrow \begin{bmatrix} -back \\ +cor \\ +strid \\ <+del.rel. > \end{bmatrix} / --- \begin{bmatrix} -cons \\ -back \end{bmatrix}$$

The change [–back] links to the coronal marking convention, where the unmarked value is [+cor] in [–back,–ant] consonants (it is [–cor] in [+back,–ant] segments). Markedness rules are linked in sequence, so the immediate result of applying coronal markedness triggers a change in the value of del.rel. to plus (because of the changed value of coronal), and finally a change in stridency. To block this chain of secondary feature modifications and allow the output to be [k^y g^y x^y], the rule simply needs to explicitly specify that [coronal] is not changed:

(14)
$$[-ant] \rightarrow \begin{bmatrix} -back \\ -cor \end{bmatrix} / _ \begin{bmatrix} -cons \\ -back \end{bmatrix}$$

Because reassignment of the value of coronal is preempted with such a formulation, further changes to the segments do not arise. The added complexity of the latter rule predicts that $[k^y g^y x^y]$ will be a less common form of velar palatalization. Stanley (1967: 404) similarly proposes that the output of any rule is subject to the segment structure rules of the language, so if a segment structure rule requires non-low back vowels to be round, then any rule inserting a non-low back vowel automatically undergoes the roundness redundancy rule.

Other limitations on rule operation were proposed, with researchers seeking a way to capture recurring and potentially universal generalizations while maintaining simple notation. An example of such a rule-external constraint is the Crossover Constraint (COC) (Howard 1972), which limits the interpretation of variables in phonology.¹² Given the adoption of rule iteration, the star-parenthesis notation became superfluous, and was suspicious insofar as it was only used to express the notion "any number of possible rule foci." Elimination of the notation allowed a constraint on material appearing between the target (focus) and trigger (determinant) in a rule: "No segment may be matched with an element other than the focus or determinant of a rule if that segment meets the internal requirements of the focus of the rule."

The Crossover Constraint was seen as a constraint on string-to-rule matching, and not on possible rule statements. This allows a simple statement of the Menomini vowel raising rule with no mention of intervening features, which affects all long mid vowels and intentionally skips over all vowels, but extensionally does not skip long mid vowels:¹³

(15)
$$\begin{bmatrix} +syl \\ -low \\ +long \end{bmatrix} \rightarrow [+high] / _ C_0 (VC_0)_0 C \begin{bmatrix} -cons \\ +high \end{bmatrix}$$

The effect "anything besides a long mid vowel" is determined by universal principle.

A related constraint is the Relevancy Condition (RC) (Jensen 1974):

Only IRRELEVANT segments may intervene between focus and determinant in phonological rules. The class of segments defined by the features common to the input and determinant of a rule is the class of segments RELEVANT to that rule, provided at least one of the common features is a major class feature. If there is no common major class feature, then ALL segments are relevant.

This constraint operates in the context of a theory which (apparently) only had a generalized variable X and no infinite abbreviatory expressions. See Odden (1977, 1980), Jensen and Stong-Jensen (1979) for discussion.

Guerssel (1978) proposes the Adjacency-Identity Constraint (AIC):

Given a string A_1A_2 where $A_1=A_2$, a rule alters the adjacency of A_1A_2 if and only if it alters the identity of A_1A_2 .

The purpose of this constraint was to explain why certain rules did not affect geminate segments: for example, vowel epenthesis is blocked from splitting up geminate clusters.

Another constraint of the era, governing whether a rule could apply, was the Revised Alternation Condition (RAC) (Kiparsky 1973), a global constraint which states that "Non-automatic neutralization processes only apply to derived forms." The purpose of this constraint is to block application of rules such as assibilation in Finnish, which do not apply to lexical /ti/ sequences in [äiti] 'mother' but does apply to derived sequences, for example, [vesi] \leftarrow /vete/ 'water', [halusi] \leftarrow /halut+i/ 'wanted'.